# Instruments

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# Measurement and Control

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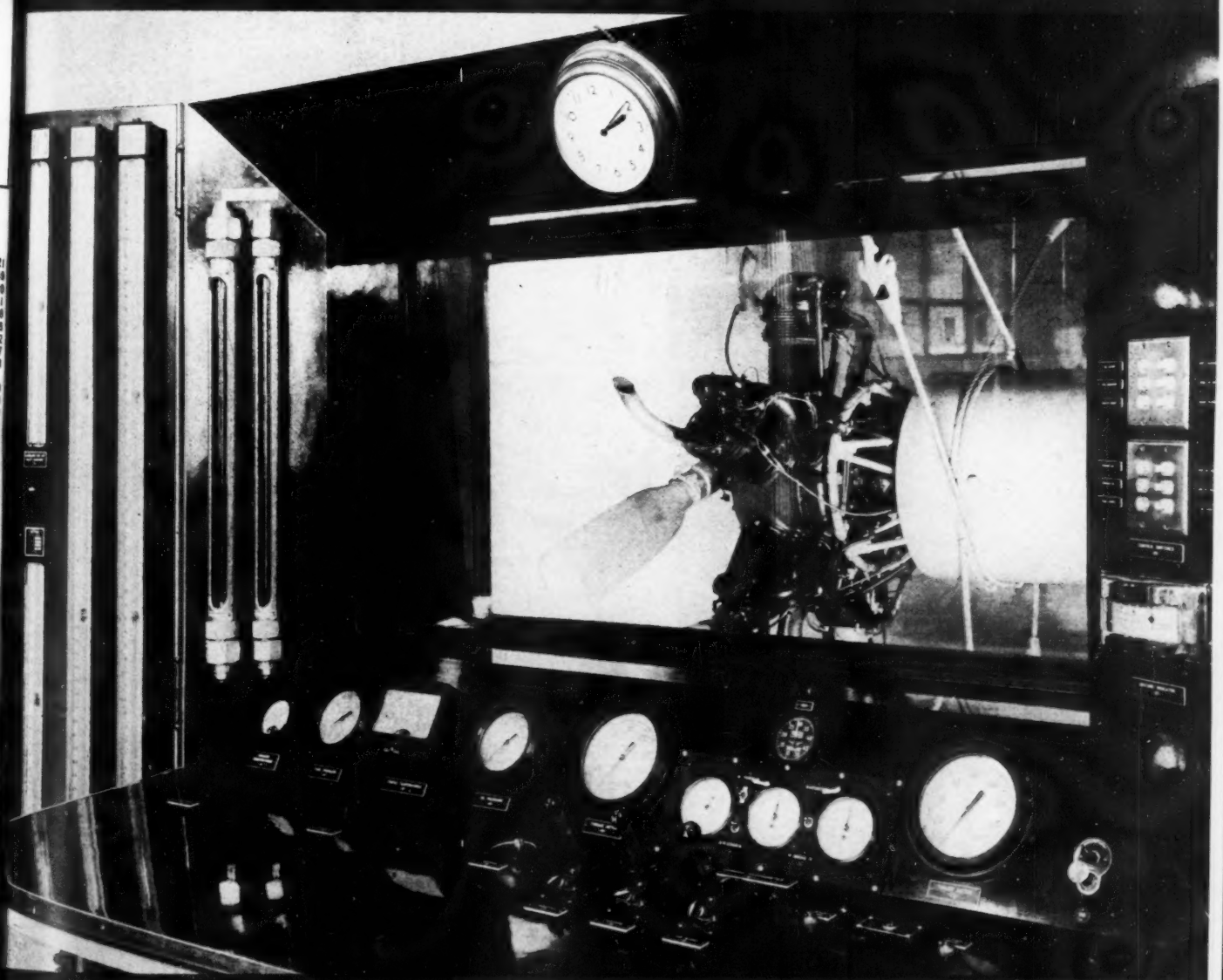

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## Aviation Instruments

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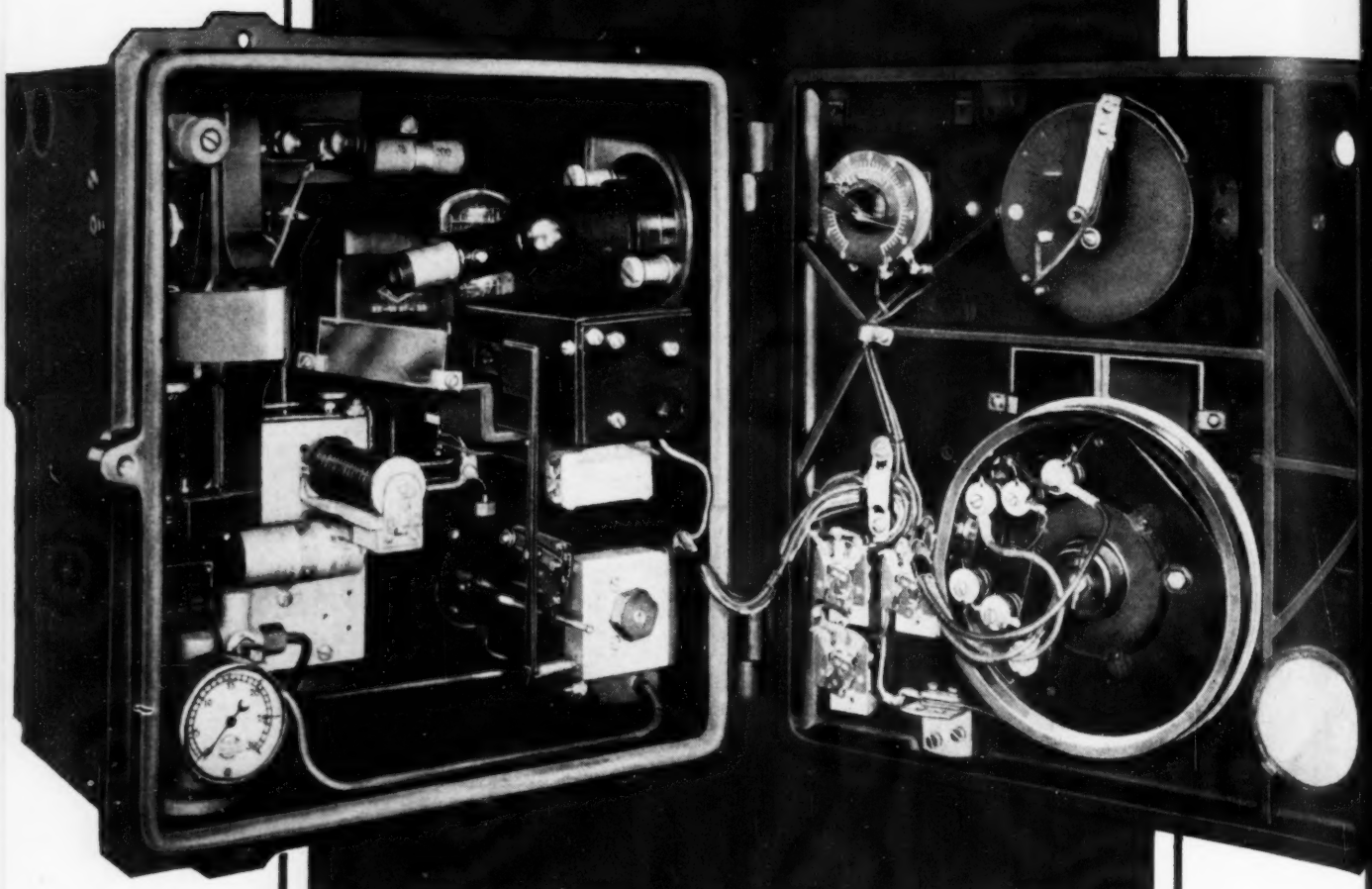

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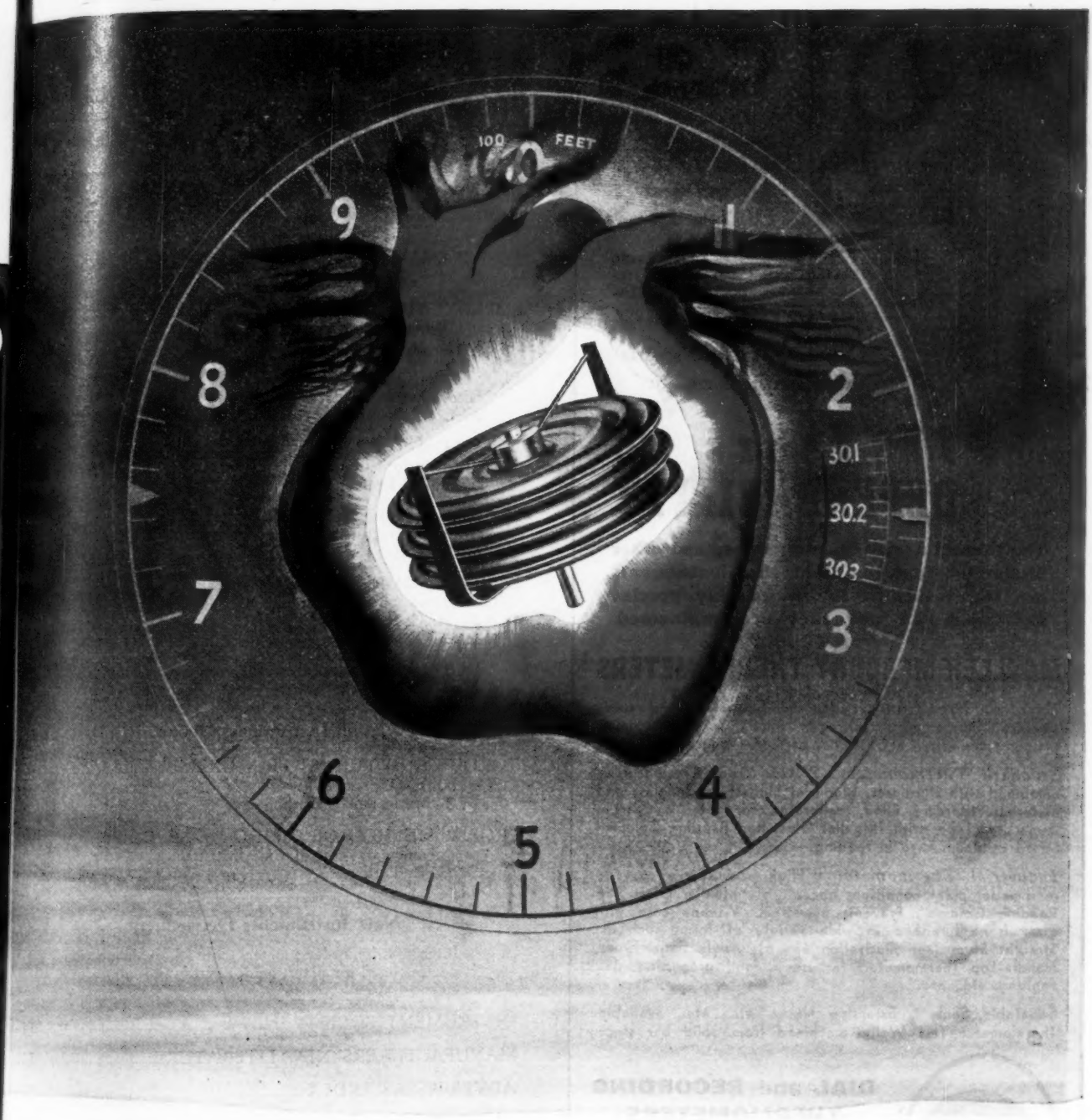


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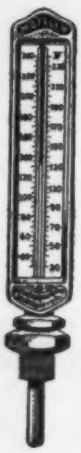

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# Instruments

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Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

All of us instrument-users mourn the sudden loss of two eminent instrument-makers.

EDWARD BAUSCH, Chairman of the Board of the Bausch & Lomb Optical Co., died on July 30 at the age of 89. A son of John Jacob Bausch, one of the founders of the company, he early evinced skill in optical design as well as executive ability, won many honors from scientific and engineering societies.

EDGAR HIEL BRISTOL, President of The Foxboro Company, died on July 24 at the age of 73. Possessed of extraordinary mechanical skill, he first served as production manager of his father's instrument company, then in 1908 withdrew with his brother to organize the firm which in 1914 became The Foxboro Company.

# Echoes of the Automatic-control "Mystery"

IN the last four months, great events have perhaps made the majority of *Instruments* readers forget the automatic-control "mystery" reported on this page last March: a friend's claim that he made a thermoregulator with a .06°F. dead-zone maintain a laboratory bath to ±0.003°F. by a new method of control (undisclosed).

The unforgetting minority is an enthusiastic one, to judge from their letters. Four deserve honorable mention:

1. Captain C. J. Penther (Long Branch, N. J.) formerly with Shell Development Co. where he helped design high-precision viscosity-bath control systems (0.01°F. max. gradient) and the world's fastest high-sensitivity direct-pen strip-chart recorder, encloses descriptions of these, lay stress on proper stirring and concludes:

> I believe that many builders of "perfect" baths would be much surprised and greatly disappointed if they made a temperature survey of their equipment with a really sensitive high-speed thermometer and recorder.

2. Samuel E. Pond (Thompsonville, Conn.) denies his pals' rumor that he is the hero of my March editorial, discusses static and dynamic sensitiveness-es of thermoregulators and concludes that rarely are manufacturers' sensitiveness ratings "too conservatively reported or improved by the arrangement in the circuit or scheme."

3. Alfred S. Trask (Richmond, Va.) opines that the answer may be

> . . . a bath utilizing the constant temperature of a melting or freezing metal[1] . . . If the bath is maintained in solid-liquid equilibrium, the heat supplied may vary within rather wide limits though the temperature of the bath is unchanged—the properties of the variable proportion of liquefied material being utilized for control.

4. C. L. Milton, Jr. (Akron, Ohio) proposes the Gouy prime-relay principle[2] as a possible explanation.

Other writers likewise mentioned highly-refined prime-relay mechanisms, prime-relay electron tubes, etc. The fact remains that the relays, valves, etc., are COMMANDED by the controller's bulb: a large-diameter bulb or thick ceramic well imposes a limit to the controller's sensitiveness—a limit which the perfection of its other parts cannot reduce. Mr. Milton's letter shows an awareness of this fact; some other writers ignore it utterly. The fault may have been mine, because I printed in full my friend's challenge of my slogan that "no controller is better than its primary element" but did not reprint any of my own texts and diagrams explaining what this means. Here, then, is one of my old preachments:

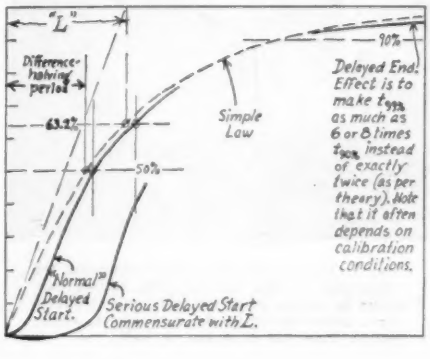
*Thermometric lag is a common source of serious error in industrial temperature measurement and control. It is a source of error in measurement because it means that the temperature of the primary element is never the same as the temperature of the medium—except momentarily when the curves cross . . .*

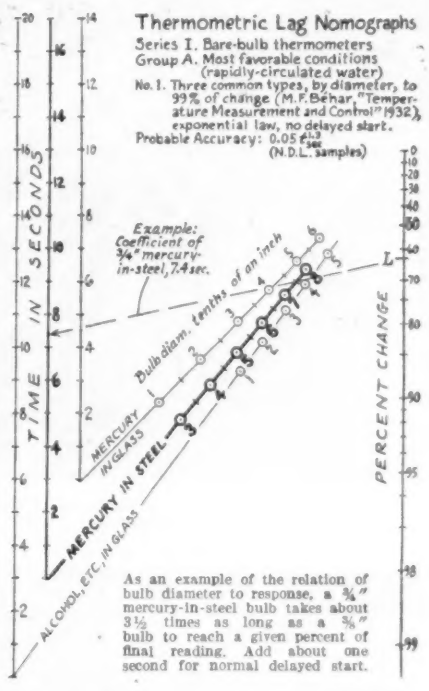
*Primary-element lag makes close control impossible . . . Reasons summarized in three slogans:* (1) NO CONTROLLER IS BETTER THAN ITS PRIMARY ELEMENT. (2) THE CONTROLLER IS ALWAYS TOO LATE WITH TOO LITTLE—FOLLOWED BY TOO MUCH—CORRECTIVE ACTION. (3) DEAD TIMES MEAN DEAD ZONES.

*Newton's Law of Cooling an over-simplification of what really happens in . . . a primary element which is not a single elementary part but a mechanical structure . . . complexity . . . structures characterized by lag curves with "delayed start" and "delayed end" . . .*

One correspondent wants me to take back my "slur" on the Beckmann thermometer, "the world's most accurate." It isn't a question of intrinsic accuracy but of relatively slow response due to large bulb diameter. Instead of taking back anything, I re-word my March assertion as a new general principle:

*The lag of the primary element of a thermometer used for checking the effectiveness of a controller must be smaller than (preferably one-third of) the lag of the controller's primary element. The circulation past the test-thermometer bulb must be as fast as the circulation past the controller primary element. The test-thermometer must be of a design and construction which exhibits neither the "delayed-start" effect nor the "delayed-end" effect.*


"L"
Difference-halving period
63.2%
50%
90%
Simple Law
Delayed End Effect is to make $t_{90\%}$ as much as 6 or 8 times $t_{50\%}$ instead of exactly twice (as per theory). Note that it often depends on calibration conditions.
"Normal" Delayed Start.
Serious Delayed Start Commensurate with L.


Thermometric Lag Nomographs
Series I. Bare-bulb thermometers
Group A. Most favorable conditions (rapidly-circulated water)
No. 1. Three common types, by diameter, to 99% of change (M. F. Behar, "Temperature Measurement and Control" 1932), exponential law, no delayed start.
Probable Accuracy: 0.05 $t^{1.2}_{sec}$ (N.D.L. Samples)
TIME IN SECONDS
PERCENT CHANGE
Example: Coefficient of ¾" mercury-in-steel, 7.4 sec.
Bulb diam. tenths of an inch
MERCURY IN GLASS
MERCURY IN STEEL
ALCOHOL, ETC., IN GLASS
L

As an example of the relation of bulb diameter to response, a ¾" mercury-in-steel bulb takes about 3½ times as long as a ⅜" bulb to reach a given percent of final reading. Add about one second for normal delayed start.

This principle—re-worded to suit—should be adopted by scientific and technical bodies and widely published, to end a source of confusion which makes good friends argue endlessly—sometimes pointlessly! I intend to release, within a few months, thermometric-lag charts and other data I have been accumulating for years, which may enable workers to spot unsuspected error sources not only in "fine" work such as laboratory baths but also in large furnaces, stills, etc. —MFB

(1) Anderson, *Review of Scientific Instruments*, Dec. 1930.

(2) Original disclosure in *Journal de Physique* in 1897; good description by Fairchild in *Instruments*, Dec. 1937.

# Employee-designed Robots at Glenn L. Martin Plant

By NILS H. LOU, Factory Manager and C. G. STEPHENS, Inspection Manager
The Glenn L. Martin Co., Baltimore, Md.

DESCRIPTIONS of all the automatic instruments in all departments of The Glenn L. Martin Company would fill a large book. Some of those used for RESEARCH and DEVELOPMENT have already been described in *Instruments*.* Practically all those used for making PRODUCTION PROCESSES automatic are already well-known to *Instruments* readers. However, for automatizing INSPECTION and TESTING, some entirely new methods have been devised. In this brief article we shall deal only with automatic devices developed by employees of this Company.

*See in particular "Measuring the Elastic Airplane" by W. E. Bender, Jr. *Instruments*, April 1942, pages 96-97, 140.

## I—Control-cable Testing

Thanks to an automatic device developed by employees in the Electrical Department of Army Division, control cables for the B-26 Marauder and other Martin bombers are now being tested for proof load in half the time previously required. Not only does the new method eliminate many manual operations, but in addition it permits the testing of several cables simultaneously.

Under the old set-up the cable was inserted in the machine and the machine placed in fast forward motion to remove all slack. The operator then shifted gears, reducing the speed to ⅛" per minute until the proper tension was reached and the machine stopped. Next he waited for the time interval required by government specifications, reversed the machine and, finally, removed the tested cable. With this arrangement cables had to be tested one at a time.

Under the new arrangement (see Figs. 1, 2 and 3) all the operator has to do is put the cables in place, start the machine in motion, and remove the cables after testing with all other operations being handled automatically by a system of electrical relay and limit switches. Pilot lights on a special panel indicate the progress of the machine throughout the entire cycle, leaving the operator free to assemble turnbuckles and prepare additional cables for testing, an operation which was recently speeded up by the introduction of a rotary airgun to assemble and remove the turnbuckles.

The new testing set-up has a load capacity of 25,000 lbs. and the number of cables which can be tested simultaneously is limited only by the proof load required for the various types of cables. These range from 288 lbs. for 1/16" 7x7 stranded construction to 17,100 lbs. for 9/16" 7x19 stranded construction. Proof load is equivalent to 60% of breaking strength.

The actual operation of the new control is as follows: After placing the cables in position, the operator puts the machine in rapid forward motion by pressing a button. When the cable becomes taut a relay is opened, automatically reducing the movement to slow speed. As the required tension is reached, the machine stops and a second relay starts a timing device. This in turn opens another relay after the required interval has elapsed, which reverses the machine and slacks off on the cables.

Finally, the machine is automatically stopped by a limit switch after it has moved far enough to permit easy removal of the cables.

Adjustments are provided for pre-regulating the amount of tension and the time interval for which the load is sustained before the tension is slacked off. The former can be varied from the number of pounds needed for the smallest cable to 25,000 lbs., the capacity of the machine. The latter is adjustable to meet requirements ranging from 3 seconds to 3 minutes depending on the type of cable and connections being tested.

In addition to this device which has cut cable testing time in half while maintaining the same high standards of safety, additional changes prompted by employees in the Army Division Electrical Department have raised the overall department efficiency 20% as compared to former established time standards.

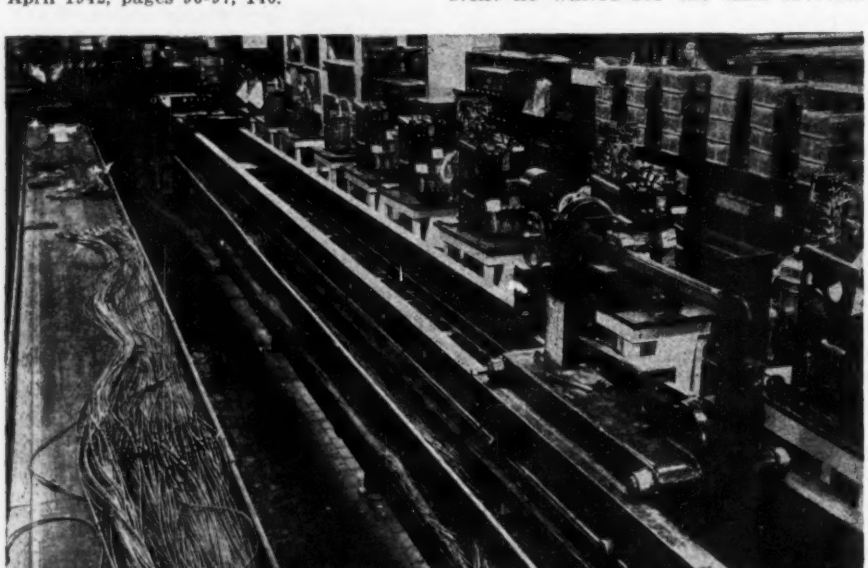


Fig. 1. General view of automatic proof load testing machine developed by employees of the Electrical Dep't, which makes it possible to test as many as four cables simultaneously.

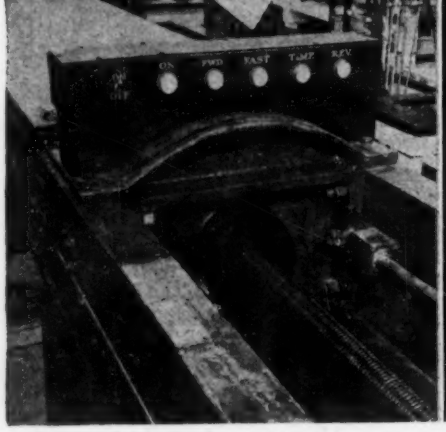



Fig. 2. Pilot lights on this indicator panel keep the operator fully informed of the progress of the test throughout the cycle of cable testing operations, and permit him to devote his time to other work.

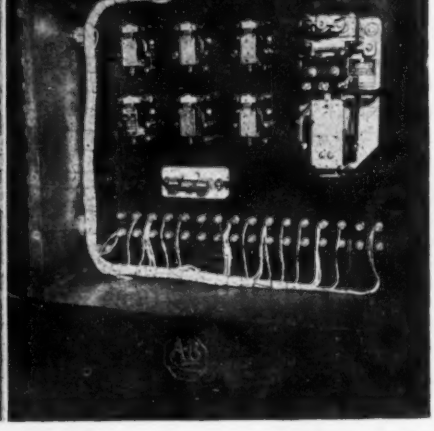


Fig. 3. This electrical set-up automatizes the operations of the control-cable testing machine by means of relays and limit switches. Since introduction of the new device, cable-testing time has been cut in half.

## II—Airplane Circuit Analyzer

The Circuit Analyzer shown in Figs. 5 and 6 has already brought about savings of 12,300 man-hours in the inspection of B-26 Marauders, while similar units are being used to bring about comparable savings on other Martin bombers. It was designed and built by four inspectors in Army Division: Joseph M. Aldrich, Jr., Willard J. Matson, James D. McCallister and Herbert R. Morawe.

The Circuit Analyzer is a compact portable unit containing equipment for testing every wire and piece of electrical equipment in the airplane, yet flexible enough to permit modification when needed to meet engineering changes. Since operation of the unit consists solely of plugging into the various circuits of the airplane, its use makes it possible for a woman with no experience to perform tests formerly requiring an experienced electrical inspector and achieve perfect results in a fraction of the time previously required.

While the Aldrich-Matson-McCallister-Morawe device was originally designed for the B-26 Marauder, the Circuit Analyzer principle is easily adaptable to any make of airplane—in fact, the Martin Company has already made up Circuit Analyzers for testing the electrical systems of the PBM-3 Mariner and other Martin bombers. Similarly the use of the device is not confined to manufacturer's inspection, and the same units can be used by service mechanics on the flight line to locate and isolate troubles.

The B-26 Circuit Analyzer is designed to actively test the wiring of the airplane section by section at a low voltage (4 volts) for continuity before the fuselage is spliced. It is designed to test and operate all operational units and the lighting systems at their required voltage. The check so supplied is precise and significant whereas previously the system was merely checked for ground and bonding with little continuity check and no checks at all on the installed equipment. Yet the previous method took two experienced inspectors eight hours to inspect one airplane as compared to two hours for the Circuit Analyzer method.

Among the many tests that can be made with the Circuit Analyzer are checking continuity of all wires in the interphone system and the proper connections in every interphone box; checking continuity on every wire, switch and light in the interior lighting system, lighting all lights if necessary; testing and operating all bells and horns; and testing all door switches.

More specialized tests handled with the same compact unit include making continuity tests of every switch, including the propeller control circuits on the engine control pedestal panel and pedestal; completely testing the bomber's switch panel, operating each and every signal light both separately and in salvo, and checking rack selector switches for proper connection and operation; testing the Autosyn and Liquidometer systems and the gun firing and gun circuits; testing and operating windshield wiper motors; testing landing gear position and locking switches, and testing and running all anti-icer, de-icer, fuel transfer and booster pumps, among other aircraft equipment.

Every main wire that runs to a switch or some piece of electrical equipment is tested by the use of cable runs connected to the test set, and other ends having Cannon plugs or terminals to connect to the plugs or terminals in the section. Wires that cannot be tested in this manner are tested on a separate circuit using a point-to-point continuity test with lights and buzzers in the circuit. The bomb system and the auxiliary boxes on all bomb racks are tested and operated from the bomber's circuit plug by an adapter circuit that works into the bomber's circuit in the test set.

The new Circuit Analyzers have been in use at the Martin Company for nearly a year and in addition to saving 12,300 man-hours in the inspection of the B-26, have lopped off many further man-hours formerly spent in rework of defective equipment and wiring. And over and above this, they have provided a safe, sure method of testing electrical circuits in which both fire hazards and the possibility of error are completely eliminated.

## III—Hardness Certifier

A mechanical device for testing and automatically certifying the hardness of sheet metal parts, designed and built by Adolph Vlcek, Jr. of the Inspection Department, has saved more than 1,050 man-hours during the last eleven months, and even greater savings are expected in the near future as additional units under construction are placed in operation. An estimated three million parts have passed through the original machine during the first eleven months of operation at an average saving of 1¼ seconds per part over the methods previously used.

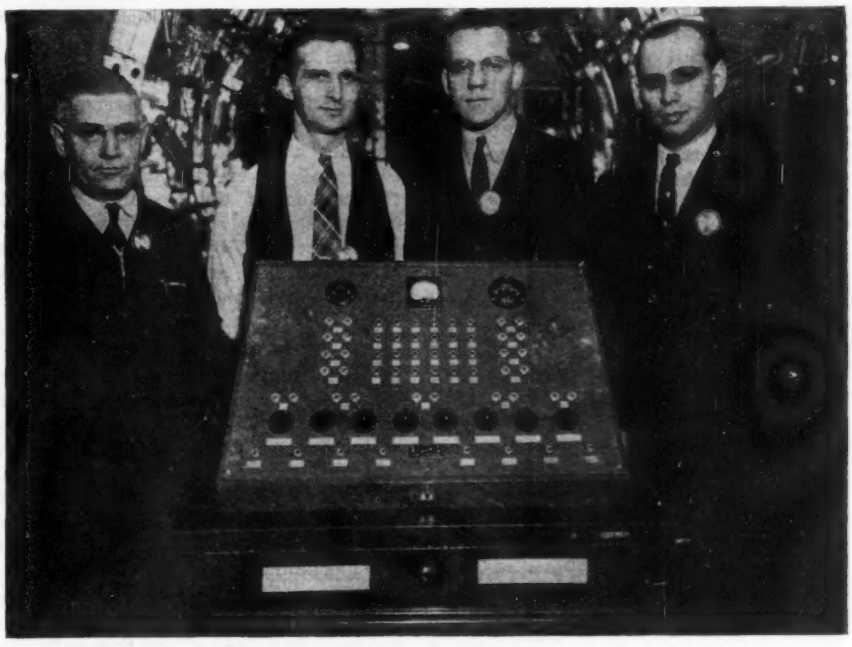


Fig. 4. The Martin Circuit Analyzer and its four inventors. Left to right: J. D. McCallister, H. R. Morawe, W. A. Matson and J. M. Aldrich, Jr.

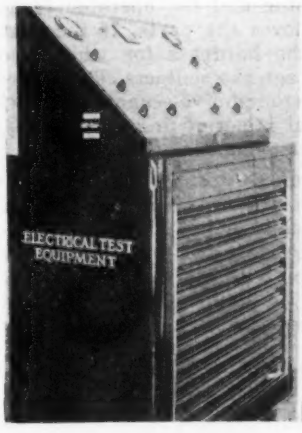



Fig. 5. Outside view of Circuit Analyzer.

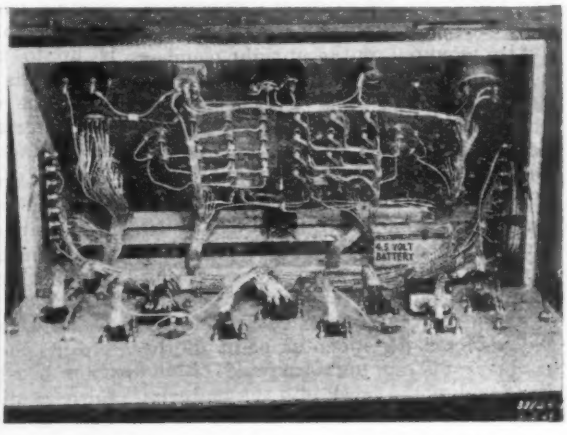



Fig. 6. Inside the Circuit Analyzer, showing some of the test circuits used to check electrical systems in the B-26 Marauder.

Known as the Martin Hardness Certifier, the new machine (Fig. 7) was invented by Inspector Vlcek not primarily as a time-saver, but as a means of *increasing accuracy* in certifying the hardness of aluminum alloy parts. Previously these parts were tested with a hand tester and the operator had to read a dial. He took about twenty readings a minute, and at this speed there was always the possibility of his reading 80 (the low limit for ST condition) when the needle actually read only 60 or 74, indicating an SO or SW condition. Another limitation of the old method was that after the parts had been tested, the operator had to take a hammer and die and stamp each part both with his personal stamp and a heat treat stamp certifying its true hardness.

With Vlcek's Hardness Certifier, the testing and stamping operations are combined and automatized, completely removing all possibility of accidental error. The machine is set for the thickness of the material and the minimum satisfactory hardness (80 in the case of ST aluminum). Parts are then fed under the indenter point of the hardness tester unit which moves up and down at the rate of 43 times per minute —the machine could be geared faster or slower, but the 43 per minute rate has been found most satisfactory in practice. If the part measures up to the specified hardness, an electrically-operated plunger automatically stamps it with both the inspector's and the hardness stamp. If it is too soft, the plunger remains inactive and the part cannot possibly be certified. The entire operation is automatic, and could, in fact, be performed by a blind operator. Both the visual reading of the hardness tester dial and the hand stamping of parts are completely eliminated.

The Hardness Certifier, itself, consists of a flat-topped base member which serves as a working table on which the parts to be tested are placed, an upright support rigidly secured to the base and an arm supported by the upright which affords a mount for the stamp mechanism — comprising a plunger and an operating solenoid. The inspector's personal stamp and that indicating the material are removably secured in the plunger.

Also mounted on the upright member is a bracket supporting the testing mechanism and the electric motor which operates it. This bracket can be raised and lowered from or toward the working surface by means of a screw and crank. A block mounted on the bracket carries bearing members, which in turn supports a lever on a pin. This lever is urged upward by a strong spring to hold the follower against an eccentric driven by the electric motor which forces the indenter point of the hardness testing unit mounted on the other end of the lever into the material under test.

The hardness testing unit is of conventional form, comprising tester, indenter point and guard. Contacts are secured to the indicator structure and wired into an electric circuit which includes a transformer connected to a source of power, a relay operated by the closing of the contacts which in turn closes other contacts, and a solenoid energized by the second set of contacts which actuates the stamping mechanism to mark the material.

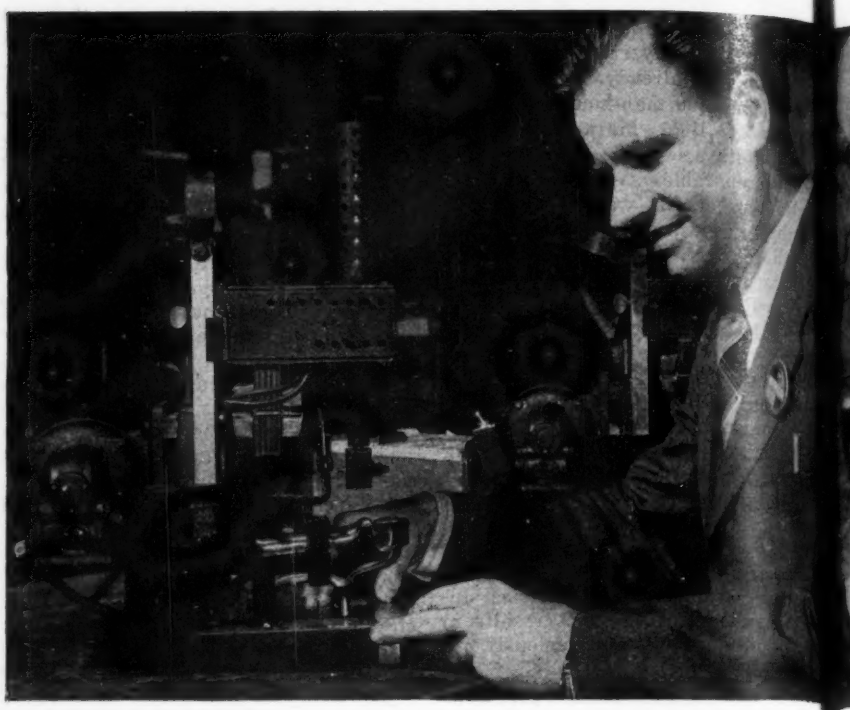


Fig. 7. Adolph Vlcek demonstrates the Automatic Hardness Certifier.

Since the indenter point must be perpendicular to the material, an extension is included on the indenter pin which serves as a height gage. This is so constructed that when the under surface of the extension is in contact with the material, the indenter point will be in the proper perpendicular position. The height gage is adjusted by raising or lowering the bracket on which the testing mechanism is mounted.

In use, when quantities of similar parts are to be inspected, an edge of one part is placed under this extension and the gage adjusted. The indenter point is then raised and lowered by the electric motor and the operator feeds in and removes the parts. If the part is up to the hardness for which the machine is set, the contacts close, operating the stamping mechanism but if the material is not of proper hardness, the contacts remain open.

The hardness tester unit is easily removed from the machine to replace a broken indenter point. The switch contact can be adjusted by spacing the contacts for various hardnesses. The impact of the stamp can be regulated by adjusting the soft iron armature within the solenoid. If an indenter point breaks, the machine will give a false reading, but as this is always a too soft reading, there is no danger of the machine certifying material by reason of a broken point.

Vlcek's original "Hardness Certifier" was built from scrap parts gathered from all parts of the plant. Several additional machines are now being built in the Martin Tool Manufacturing Dept. for use in the Martin plants, and licensing arrangements have been established with the York Electric Tool Co. under which that company is now producing the "Hardness Certifier" for the commercial market.

### IV—Rivet Sorting

Another useful robot, in the form of the automatic rivet sorter shown in Fig. 8 saves about $12,500 a year at The Glenn L. Martin Co. It was another case of necessity mothering invention. Long ago Martin production engineers had decided that it was far cheaper to let lie those aluminum alloy rivets accidentally dropped on the floor than have riveters take time out to recover them, especially since one of these workers is expected to drive about 1,000 rivets a day. Nevertheless, these rivets swept up at the end of a day represented a real problem, for their value averages over a dollar a pound and some sixty pounds of the light metal parts were swept up daily.

A team of youths had for a long time sorted rivets by hand, and they had not even been able to pay their way. From production officials an S.O.S. went out to Tool Design: "Why can't you develop machinery to sort salvaged rivets?"

Tool Design did. Most of the sorters were sent on to more important work, and today the heterogenous collection of rivets clatter down a little track from a hopper, click obligingly into little slots on a wheel and drop off the perimeter with almost human under-

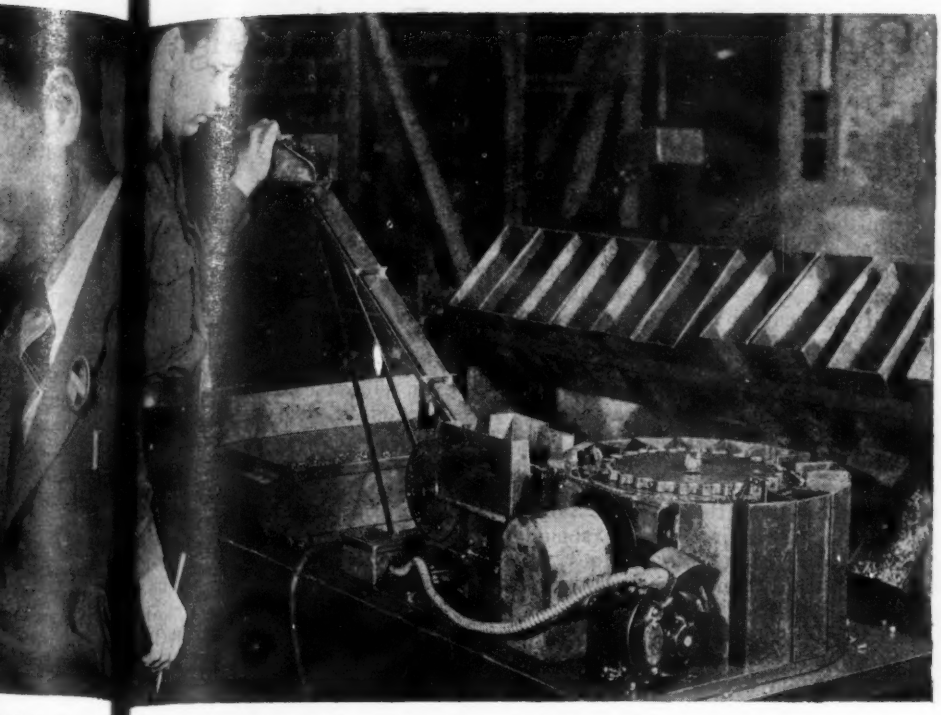


Fig. 8. The Automatic Rivet Sorter developed by Tool Design.

standing into just the right box. One is reminded of linotype matrices dropping automatically into their slots.

Although the rivet-robot is a versatile machine which can toss aside either round-head or flat-head (universal or countersunk, in factory parlance) rivets and allow the others to run through and separate themselves by lengths, there are several simple preparatory steps.

In the first place, the floor sweepings comprise, besides the rivets, a mass of screws and bolts and nuts and odd shapes of metal. Over this collection is passed an electromagnet which snatches out the extraneous steel and iron material. The residue is chiefly rivets of some 150 different kinds. A series of sifters sorts them out for diameter, in much the same way that gravel is graded.

In each diameter class there still is a wide variance of lengths and head shapes. Into the five sorters they go, each sorter handling a different class.

But here Tool Design interposed an optional intermediate step. While the length-sorting unit can also be made to toss aside either round-head or flat-head rivets while one kind or the other is being classified automatically into a dozen or so different lengths, it is necessary then to go back and sort those tossed aside. To keep from tying up the robot so long, another device separates round-head from flat-head rivets at a high rate of speed.

Since the head-selector device works twice as fast as the length-selector (sorting, for example, 100 lbs. of 7/32" rivets in eight hours, against sixteen hours for length selection) the whole job is speeded up by this far simpler mechanism without increasing the cost of doing the work.

In principle, the rivet robot is really simple: As the rivets travel, heads up and shanks down, along the inclined track from the feeding hopper, they ride into the teeth cut into the perimeter of the big wheel. A little fixed arm in their path can be adjusted to knock off either the round-head or flat-head rivets into the first of the series of small bins ranged around and below the perimeter of the wheel. Those which are allowed to go through "feel" with their shanks for the flaring springs below, which will force them off the wheel into their proper bins. The long-shank rivets fall first as the deeper springs catch them, allowing the shorter ones to pass through. Then the next longest and the next and next fall off, until the shortest lengths of all ride around to the last bin.

Where the sixty pounds a day of rivets formerly were salvaged at costs slightly greater than their actual value, they are now sorted at a cost of only a few cents per pound, saving annually about $12,500 of the $15,500 that formerly was a total loss.

## V. The "Mechanical Mouse"

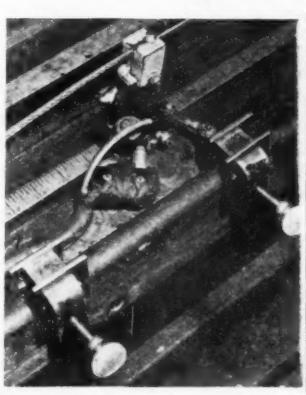
The "mechanical mouse" designed by Marvin L. Argabright, General Foreman of the Electrical Tubing and Cable Department, is likewise relieving manpower shortage. It operates on a 51-foot cable-cutting table, reducing fatigue and saving man-hours by permitting the operator to stand still instead of walking and carrying cables between measuring and other manual operations.

The "mouse" consists of a pair of spring jaws and is attached to a chain which runs along the top of the 51-foot cutting table and returns beneath the table. After swaging, the cable is placed in the "mouse" with the terminal butting against the jaws. The chain is started and the "mouse" travels forward carrying the cable until it passes a stop pre-set at the desired cable length. (See Fig. 9) A limit switch is tripped, causing the chain to reverse until the "mouse" is halted by the stop. This flashes a light which signals the operator that the cable is in the proper position to be cut.

As he cuts the cable, the shear trips another micro-switch, starting the chain forward again. The cable is then carried the length of the table and back beneath it. When the "mouse" is about three-fourths of the distance back, an angle iron spreads the jaws and the cable drops into a wooden trough. The "mouse" continues on until it trips another switch which stops it in front of the operator ready for the next cable.

The entire cycle is thus automatically controlled and the operator never moves from the end of the table. The only manual operations are attaching the cable, starting the chain and lowering the shear. While the cable is being carried along the table and dropped in the trough after cutting, the operator is left free to crimp and swage the terminal on the next cable.

The stop permits the "mouse" to pass only when traveling forward; and stops the "mouse" only when it is carrying a cable. The trip arm is made of fibre except for a metal insert to make contact with the "mouse." The jaws of the "mouse" are likewise made of fibre except for the cut-out for the cable, and insulated against each other when empty. The cable itself, when inserted, completes the circuit.



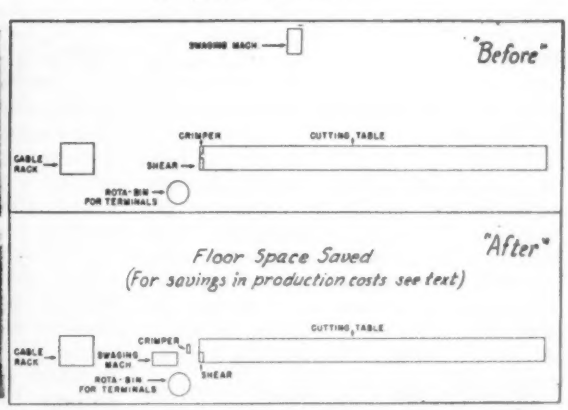



Fig. 9. The "Mechanical Mouse" and its Application.

# Industrial Temperature Instruments Employing Electronic Methods and Devices*

By C. O. FAIRCHILD, Director of Research, C. J. Tagliabue Mfg. Co., Brooklyn, N. Y.

RUGGEDNESS and simplicity account for the present acceptability of electronic devices in industrial instruments. That they can be substituted for mechanical parts that wear out, and that rapid operation and quick response are easily attained through their use, are well-known facts. But tubes would be of little value for industrial instruments if they were fragile and capricious. To be sure, the phototube (not the photovoltaic cell) is yet to be found useful as a calibrated device, and the simple vacuum-tube voltmeter is somewhat unreliable, but their capacity for operating an unlimited number of times without failure is outstanding.

What determines the useful life of a phototube or hot-cathode tube? More

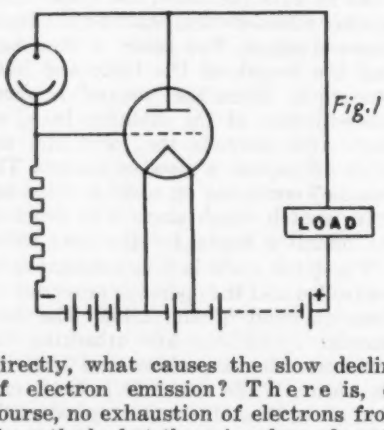


Fig. 1

directly, what causes the slow decline of electron emission? There is, of course, no exhaustion of electrons from the cathode, but there is a loss of available emitting material. In the phototube, the sensitive layer of material on the cathode is very thin and slowly disappears through evaporation and chemical action. Good tubes, that is, those made with careful control of the manufacturing processes, used conservatively, not overheated (above 160°F. approx.) by too intense illumination, will last for many years. The more sensitive gaseous phototube is the more easily injured by slight overvoltage, while the high-vacuum tube will withstand voltages far above the minimum required. We will find presently that the high-vacuum tube in combination with an amplifier may be more sensitive than the gaseous tube in such a combination.

The useful life of a hot-cathode tube is determined almost wholly by the temperature chosen for operating the cathode. The commonly-specified voltage for the cathode heater has been selected to maintain the cathode well above the minimum temperature required to provide maximum emission. At such a voltage the tube life is measured in thousands of hours—in months. Selecting a voltage a few percent lower increases the life to tens of thousands of hours, or years. This statement applies if the heating of the cathode by bombardment due to the anode current is a minor effect. Now, this lower voltage does not materially reduce the maximum emission, but it does reduce the margin of safety above lowest line voltages, *if relatively high anode currents are required for normal use.* We may conclude then, that electron tubes used in industrial instruments should be operated at conservative values not only of cathode temperature but also anode current.

CIRCUITS

The simplest electric circuit combining the vacuum phototube and its accompanying amplifier tube for detecting (for example) the light reflected from a mirror-galvanometer and thereby operating a relay or motor, is shown in Fig. 1. Here the tubes have a common battery, and their anodes are connected together. Illumination of the phototube causes the amplifier anode current to increase because the grid of the latter becomes more positive. We will not describe the more awkward connections in which illumination of the phototube reduces the amplifier anode current. The principal characteristics of the phototube in which we are now interested are shown in Figs. 2 and 3, showing, respectively, curves of photoelectric current versus voltage at constant illumination, and the current versus illumination at constant voltage, there being no external resistance in series in either case. If an external resistance is included, the graph in Fig. 3 will have less slope, but will remain straight provided that the tube voltage remains beyond the knee of the curve shown in Fig. 2. For example, if the photoelectric current is 1 microampere and the series resistance is 100 megohms, the applied voltage must be well over 100 volts.

The so-called caesium oxide phototube is preferred for use in industrial instruments because it is sensitive

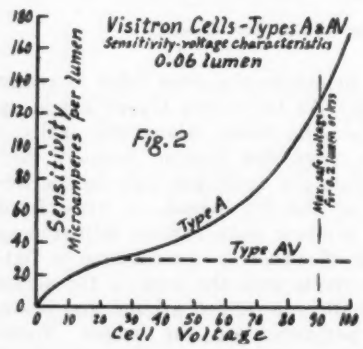


Fig. 2

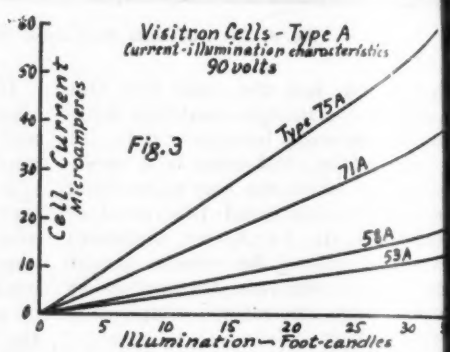


Fig. 3

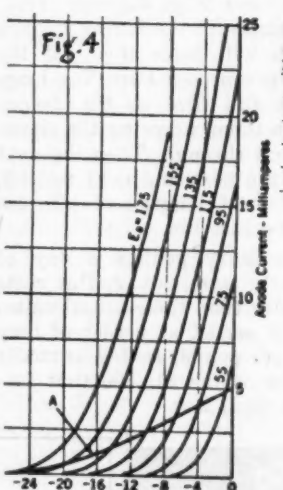


Fig. 4

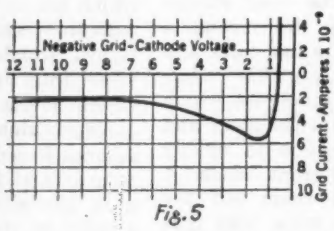


Fig. 5

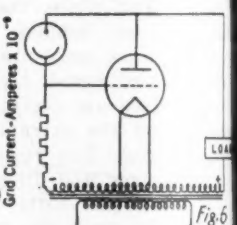


Fig. 6

red and infrared light, thus permitting the operation of the lamp source at a relatively low temperature to give long life.

Triode amplifiers are available for use in the circuit of Fig. 1 which will amplify the photoelectric current as much as 200,000 times. The amplifier characteristics required to do this are high transconductance and low reverse grid-current. (We are not referring here to the expensive "electrometer tubes" having exceptionally low grid current, and designed to give an output measured in microamperes.) Transconductance, sometimes called mutual conductance, is $di_b/de_c$, the slope of the straight parts of the curves shown in Fig. 4. The less well known grid-current curve for a low-grid-current tube is shown in Fig. 5. If this characteristic is favorable, high resistance in the grid circuit can be used safely, and high current amplification obtained.

The simple arrangement shown in

*Presented before the Society for Measurement & Control (New Jersey), June 6, 1944.

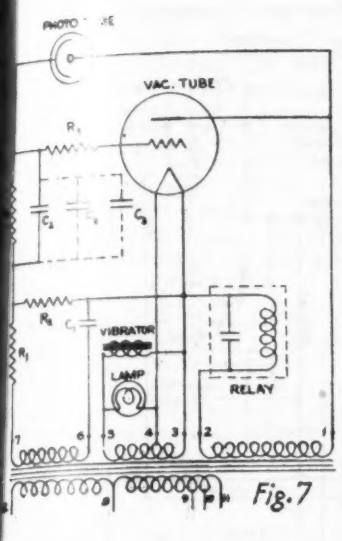


Fig. 7

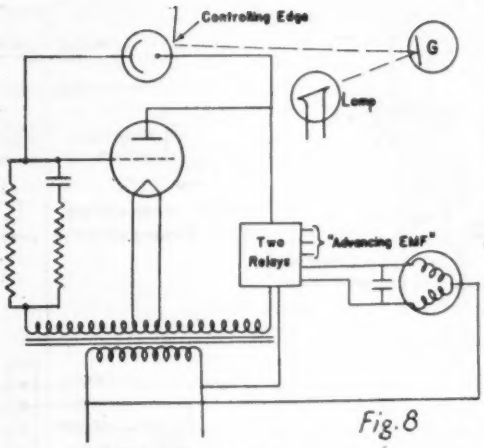


Fig. 8

ig. 1 is not generally useful because e tubes are battery-operated. This mitation is removed in Fig. 6 which ows a-c. operation and self-rectification. In this circuit anode currents flow hen the alternating voltage is positive s shown, and a positive grid current ows when the voltage becomes negative. This grid current is sharply mited, however, by the high resistance series, and may be harmless. A latively high negative grid bias is quired, and as a result the circuit ay provide fair self-regulation against anges in line voltage. This circuit still faulty in this simple form, since he load may seriously upset the phase lation between grid and anode voltges. Before attempting to improve it, e may note that response to illumintion is instantaneous, although there ay be some delay in the loading device.

### INSTRUMENTS USING A GALVANOMETER

In these, the galvanometer + phototube constitute a first stage of amplification, in which a power amplification of one to two million is easily obtained.

The circuit used in "Celectray" indicating controllers (not self-balanced) is shown in Fig. 7. A capacitor shunted by the grid resistor has been added. If this is small, the response of the circuit to light on the phototube is nearly instantaneous; if it is large the circuit is more damped and will have a response as slow as may be desired. Thus if the grid circuit is given a time constant of a few seconds and a galvanometer is used having a much shorter period of vibration, the circuit will not respond to vibration of the galvanometer. The addition of the capacitor makes it expedient to add also a grid-current suppressing resistor at the grid connection. Means for keeping the electrode voltages in proper phase relation are found in the power supply.

The relay in Fig. 7 can carry ordinary electric contacts for electric power circuits, or a throttling orifice for pneumatic control circuits. In either case, it constitutes a third stage of amplification and, in the pneumatic controller, the follow-up mechanism is not connected to the primary system but follows the light beam from the galvanometer.

A slightly modified circuit, Fig. 8, is used in "Celectray" self-balancing instruments. The effect of the addition of a resistor in series with the grid capacitor may be briefly described as follows: A sudden change in the illumination of the phototube causes a sudden change in the photoelectric current in this added resistor. The change in the voltage drop in this resistor is immediately imposed on the grid of the amplifier tube, before the voltage across the grid capacitor changes appreciably. As the charge on this capacitor starts to change, the grid voltage continues to change in the same direction, but at a much lower rate than at first. In the anode circuit of the amplifier we find then, for example, that if the light on the phototube suddenly increases, the anode current jumps to one high value and then continues rising toward a still higher value. The first value is selected to be between the operating currents of two relays in the instrument, which control the motion of the balancing motor.

Suppose that the measuring circuit of the instrument is unbalanced and that the motor is running to drive the index upscale. The galvanometer has deflected the light beam off the phototube and both relays are open (deenergized). An "advancing e.m.f." has been applied to the galvanometer so that the light beam reaches the edge of the phototube before the motor reaches the balance point. As soon as light from the galvanometer mirror strikes the phototube, the amplified current is sufficient to close one of the relays. This relay removes the advancing e.m.f. from the galvanometer, causing it to stop quickly (occasionally throwing the beam back off the phototube), and also applies a braking current to the motor. If the motor stops before it reaches the balance point, and the beam swings back off the tube, the relay starts to oscillate independently at a rate faster than the galvanometer can swing, while the light beam hovers part on and part off the tube, and the motor takes forward steps, until the balance point is reached. If the advancing e.m.f. is small enough the motor may pass the balance point, causing the light to remain on the phototube long enough for the amplified current to increase to the closing value of the second relay. This reverses the motor and the balance point is approached from the opposite direction. Too small an advancing e.m.f. will result in hunting, unless the dead zone is large.

A typical potentiometer circuit of "Celectray" instruments is shown in Fig. 9. Note that in these instruments the balancing motor runs at constant speed to a substantial balance. Note also that the electronic and power circuits are neither connected nor coupled with the measuring circuit, and act coördinately with the measuring circuit only through the instrumentality of the moving beam of light reflected from the galvanometer. These instruments were not designed primarily for high-speed recording but for simplicity, there being only one phototube and one amplifying tube used, but speed was a natural consequence of the employment of electronic devices, and in most applications it is not necessary to use the full speed possible in this class of instruments.

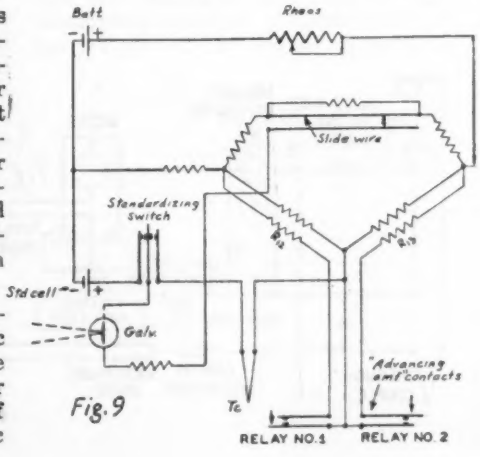


Fig. 9

### WESTON PHOTOELECTRIC POTENTIOMETER

A distinctly unique and probably the fastest self-balancing potentiometer is the Weston. The fundamental circuit is shown in Fig. 10. The anode current of the amplifier is fed back into the galvanometer circuit, and through small deflections of the galvanometer, acts to control the grid voltage by means of two phototubes in the path of the light from the galvanometer mirror. The two phototubes are connected

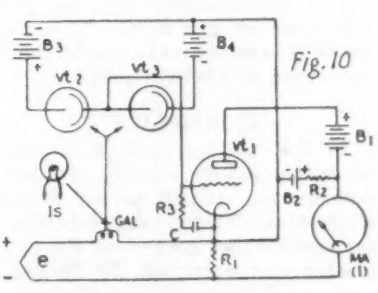


Fig. 10

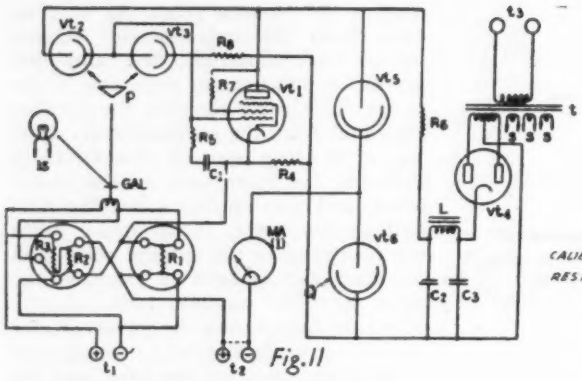


Fig. 11

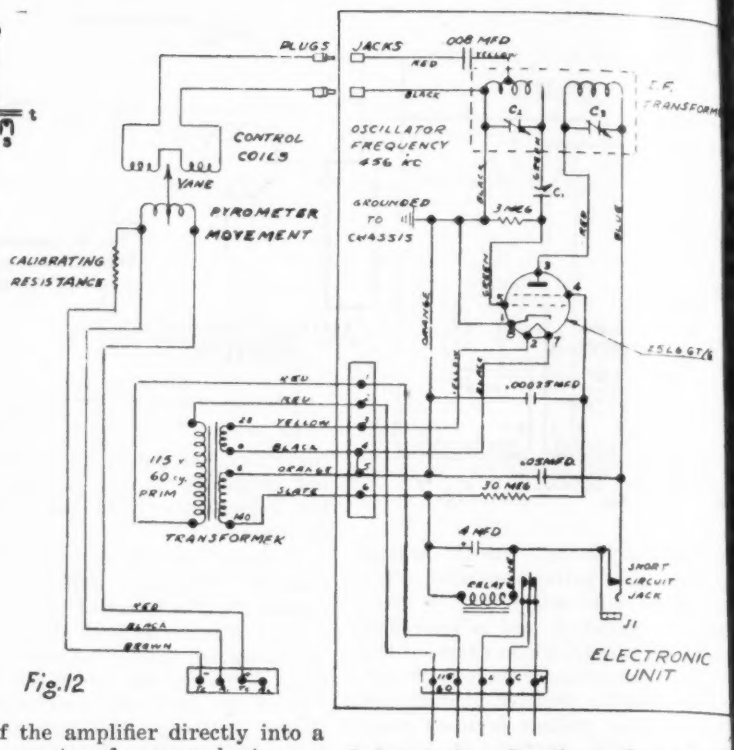


Fig. 12

in a closed series circuit with two batteries, and as one or the other tube is illuminated, the grid voltage is shifted from the positive end of one battery to the negative end of the other. The electronic circuit is damped somewhat by a shunted capacitor in the grid circuit so that in combination with the double-pivot galvanometer the whole system will not oscillate, or hunt.

The galvanometer by itself has a very long natural period of vibration and low torque, but in combination with the circuit, the anode current supplies the effective restoring torque, which can be made as large as required to give a short period. With proper damping the circuit can include either a milliammeter or a recording milliammeter such as a Bristol or Esterline-Angus. These are available with deflection periods as small as 0.5 second.

As a potentiometer, the arrangement provides for the adjustment of a current in a fixed resistor instead of moving a contact along a slide-wire in a constant-current system. This fixed resistor is common to both electronic and measuring circuits. While the effect of line resistance in the thermocouple circuit is negligible, since so minute a deflection of the galvanometer is required for full-scale operation, the error of measurement lies principally in the milliammeter. The net result is a high figure of merit which combines speed and fair accuracy.

Inasmuch as neither the phototubes nor amplifier acts as a calibrated unit, the scheme is readily adapted to a-c. operation, as shown in Fig. 11. Separate rectification and voltage regulation are provided, and a pentode is selected as amplifier, possibly to fit the high-resistance circuits required for current measurements.

The phototubes are the caesium oxide type, not the Weston photocell. The latter can be substituted for a thermocouple and used as a radiation pyrometer in combination with the Weston potentiometer, and these with a recording milliammeter make one of the fastest arrangements available.

### AUTOMATIC CONTROL

At this point it will be interesting to touch briefly on the subject of temperature control as an aspect of electronics. Weston suggests the use for temperature control of the potentiometer just described, by feeding the output of the amplifier directly into a saturable reactor, for example, to control the heating current. The feedback to the galvanometer and the potentiometric effect as arranged in the basic Weston scheme are lost in the shuffle, however, and we have merely galvanometer, phototube, amplifier and output control current. This is easily arranged with the "Celectray" indicating controller, should one want to do it in this manner. True throttling control with no moving parts other than the galvanometer results in either case. The fly in the ointment is that the equipment required between instrument and electrically-heated unit is usually too expensive. The Wheelco or "Celectray" throttling controllers of the Gouy type require only a contactor. In either the expensive or the cheaper scheme, high sensitivity is readily obtained, and in the latter, there is no instrument deadzone at all. In the former or reactor scheme, damping to counteract hunting can be included in the amplifying system, as in the Weston potentiometer.

The motor drive that used to be employed to make a controller out of a millivoltmeter is no longer required, and we now have what we may call the millivoltmeter electronic controllers, of Wheelco, Bristol and Illinois Testing Laboratories. In these the millivoltmeter pointer acts, undisturbed, to change the amplitude of radio-frequency oscillations, and operate a relay. Sensitivity to quite small deflections of the pointer is attained, with little if any risk of instability of the oscillator, which has only to furnish a few watts steady output. The scheme is essentially an electronic relay, and we will not include further details. A typical circuit, that of the Bristol Electronic Controller, is shown in Fig. 12.

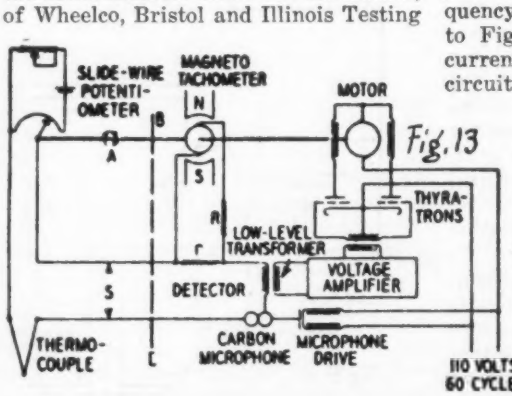


Fig. 13

### INSTRUMENTS USING A SYNCHRONOUS VIBRATOR

The question was asked many years ago: Why not amplify the current from a thermocouple and use a less sensitive galvanometer or none at all? Early attempts were made and some patents granted, but so far we find no successful means for keeping direct-current amplifiers sufficiently stable, and at the same time sensitive enough to start with a few microvolts. One of the earliest successful solutions of this problem is found in the Leeds & Northrup "Speedomax," in which the thermocouple circuit includes a carbon-microphone modulator driven at line frequency, for conversion to a.c. Referring to Fig. 13, the a-c. component of the current flowing in the thermocouple circuit when the potentiometer is unbalanced, is amplified and fed into a push-pull transformer connected to the grids of two thyratrons. The anodes of these are directly connected to two field windings of a series commutator (d-c.) motor, which drives the contact of the slide-wire potentiometer.

With the items so far described, rapid balancing of the potentiometer would not be possible; on the other

and, a slow balancing and a large dead-zone in which the motor could come to a stop would be necessary. The principal reason for this is that motors generally have poor speed-torque characteristics, and thus it is impractical to so adjust the a-c. amplification at some lower value such that the output of the amplifier will gradually decrease, slowing the motor at the corresponding distance from the balanced condition.

The amplification is kept high enough so that a few microvolts of unbalance of the potentiometer results in full output of the thyratrons and full torque on the motor. It is readily apparent that if the a-c. component in the thermocouple circuit is adjusted to be in phase or 180° out of phase with the thyratron anode voltage, only one thyratron can be fired at a time. Which one is fired is determined by the polarity of the d.c. in the thermocouple circuit, reversal of which changes the phase of the a-c. component 180°.

The anti-hunting (damping) scheme used in the "Speedomax" is to drive a d-c. generator on the same shaft with the balancing motor, and feed back the generated d.c. into the thermocouple circuit, in such a direction as to oppose the thermoelectric current. Suppose that the potentiometer is suddenly unbalanced. One of the thyratrons will immediately fire and start the motor, which speeds up until the generator output reduces the d.c. in the thermoelectric circuit to zero, and then reverses it. At this moment the one thyratron goes out and the other fires, putting full braking torque on the motor. A nicety is found in designing the generator to produce an emf. proportional to the square of the speed, so that the energy made available to stop the motor from the maximum speed reached will be proportional to the amount of unbalance. It follows that there will be a strong tendency for the motor to stop at the balance point, instead of overshooting or stopping short, and thus faster balancing can be attained because there will always be the required minimum of braking energy available. Essentially, the balancing system is critically damped, in the ideal case, and a little overdamping required for avoiding any tendency to overshoot under adverse conditions is obtained by increasing the feed-back from the generator.

There has recently appeared another self-balancing potentiometer, similar in some respects to the Speedomax but designed for lower speed. This is the new Brown "Electronik" recorder in which, referring to Fig. 14, we find in the thermoelectric circuit a synchronously-driven vibrating switch, for reversing the thermoelectric current through two halves of a center-tapped transformer to obtain an alternating voltage which is then fed into the amplifying system. The permanent magnet shown in this switch functions with the a-c. coil to give 60-cycle vibrations. As before, the generated a-c. voltage is in phase or 180° out of phase with the supply voltage, and the current is proportional to the d.c. resulting from unbalance of the potentiometer. The alternating current is amplified (3 stages voltage, 1 stage power) as indicated and is used to govern the balancing motor. We find this motor in Fig. 15, a two-phase induction motor, one field winding being connected to the supply line and the other to the last or power stage of the amplifier. Here are a pair of vacuum triodes, and it is apparent that their output varies with the amplified a-c. voltage. Since their anodes are connected in push-pull and their grids connected together, that one of the two tubes will deliver power, whose anode voltage is in phase with the amplified a.c. The half-wave pulses from this tube are smoothed by capacitor $C_1$, and an alternating voltage appears across the reversing field of the motor, in phase or 180° out of phase with the supply voltage. Capacitor $C_2$ serves to advance the phase of the voltage on the other field by 90°. Hence the reversing field leads or lags the other field by 90° and the motor runs one way or the other accordingly, until the potentiometer is rebalanced. As the balance point is approached, the output from one of the power tubes decreases, and that of the other increases, until at balance the outputs are equal with no signal on the grids, and the motor has slowed down and stopped. An adjustment is available in the voltage amplifier for matching the amplification with proper damping of the rebalancing operation, so that this will come about promptly without overshooting.

In Figs. 13 and 14, showing circuits of the "Speedomax" and "Electronik" recorders, electrical shields for the measuring circuits are not shown. These shields are essential because the circuits are electrically coupled to the primary stage of the amplifiers, and thus can act as electrical pick-ups of ambient fields.

The special adaptations of the "Speedomax" and "Electronik" systems to the rapid recording of a large number of temperatures is beyond our present scope. The former is fully described in the paper "High-speed Multiple-point Potentiometer Recorder" by Stein, Williams and Clark, presented before the ASME last December and printed in the January *Instruments*. This instrument was designed for recording the temperatures of 140 thermocouples in less than 4 minutes, or 1.63 seconds per couple.

### ELECTRONICALLY-BALANCED A-C. BRIDGE

One of the most important articles found in the recent Temperature Symposium of the American Institute of Physics is "Thermoelectric Thermometry," by Wm. F. Roeser, on the measurement of temperatures with thermocouples. The background of this title is the present extensive use of thermocouples for measuring temperatures below a red heat. To be sure, resistance thermometers are not on the other hand extensively used as pyrometers,

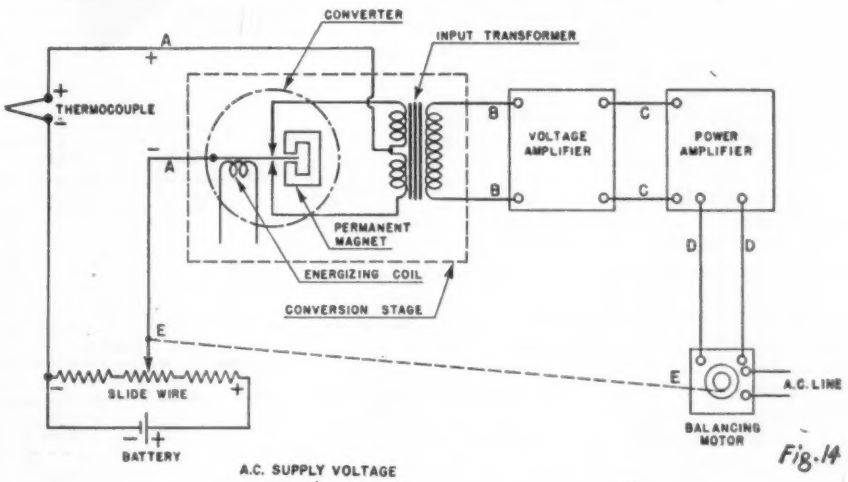



Fig. 14

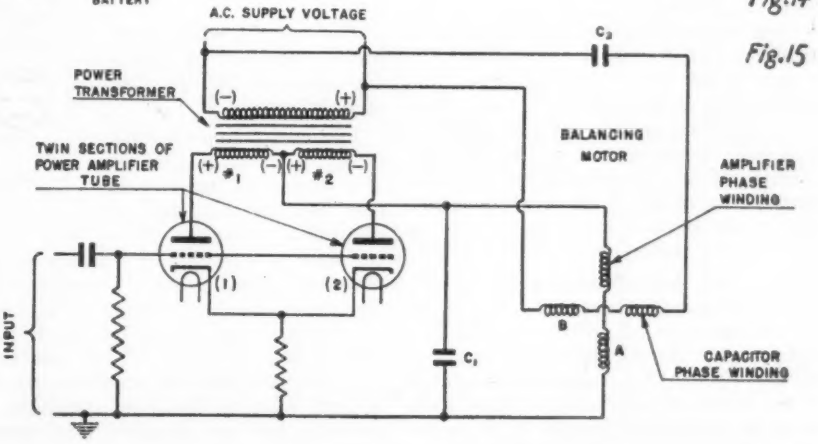



Fig. 15

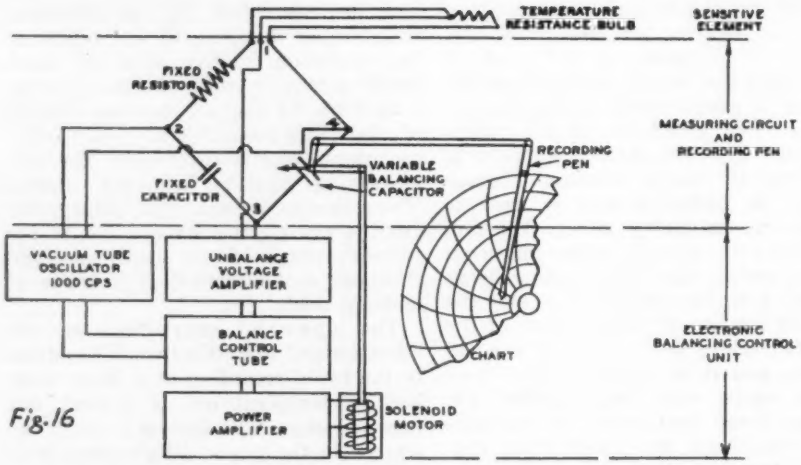



Fig. 16

but nevertheless we feel justified in including the electronically-balanced a-c. bridge used with a resistance thermometer as in the Foxboro Electronic Recorder. A simplified functional diagram of this instrument is shown in Fig. 16. The bridge is supplied with low-voltage 1000-cycle a.c. and the unbalance voltage is fed directly to the amplifier. The synchronous vibrator is of course missing, and the problem of amplifying is benefited by use of an audio frequency instead of 60 cycles. The problem is also eased somewhat by the fact that the resistance thermometer can be operated at a large fraction of a watt, so that the unbalance voltage may be large compared with that found in the potentiometer and thermocouple circuit. Here, the amplifier operates a solenoid motor which is attached mechanically both to a variable capacitor in the bridge and to a recording pen-arm. The essential mechanical features are shown in Fig. 17, in which it is found that the damping or anti-hunting device is a hydraulic dashpot holding a liquid of low temperature coefficient of viscosity.

Regarding this recorder as a control mechanism, its basic method of operation is throttling or corresponding control without reset, and in this respect it differs from the recorders described above and resembles the Weston Photoelectric Potentiometer. This means that a slight residual unbalance of the bridge is required to hold the solenoid motor away from its position of mechanical balance. This residual is very small, and balance may be described as complete because of the high amplification found in the electronic system. Since the highly-amplified unbalance signal is returned to the bridge as a restoring motion of the variable balancing capacitor, adequate damping is required to prevent oscillation of the motor. The speed of balancing is probably of the same order of magnitude as that of the recorders described above.

The electronic problem is again that of detecting a phase reversal according to the direction of unbalance and amplifying the signal. Referring to Fig. 16, the alternating potential of point 2 in the bridge is 180° out of phase with point 4. Unbalance results in a potential of point 1 which is in phase with that of 2 or 4 depending on the direction of unbalance.

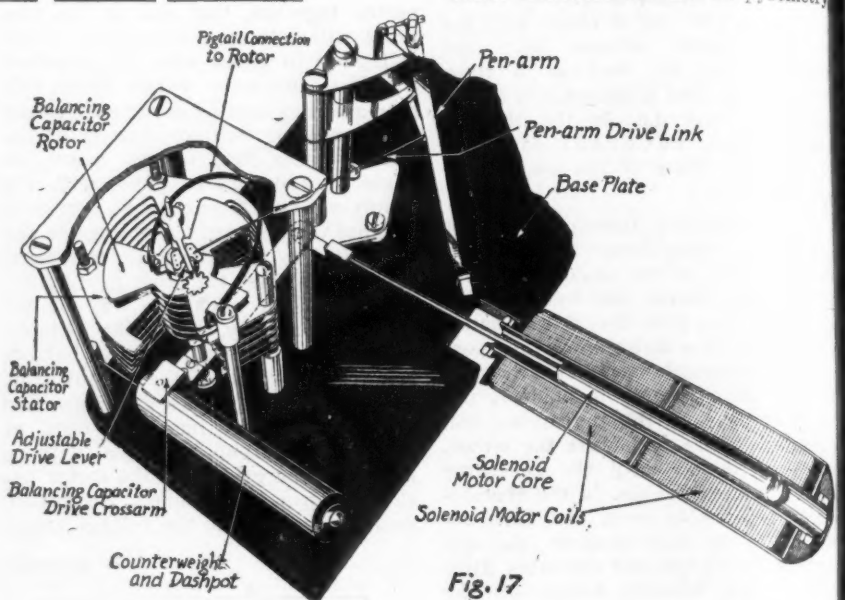



Fig. 17

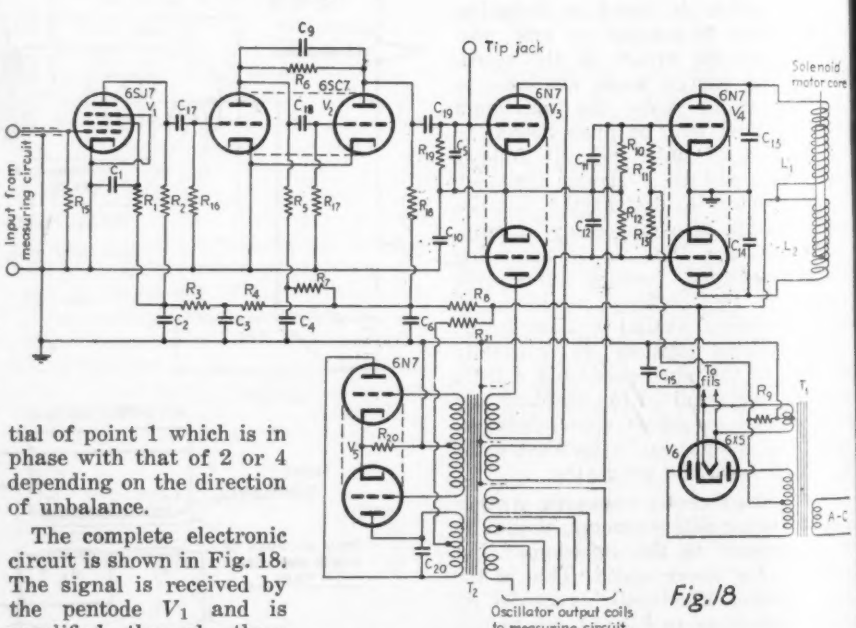



Fig. 18

The complete electronic circuit is shown in Fig. 18. The signal is received by the pentode $V_1$ and is amplified through three resistance-coupled stages to the phase-reversal detecting tube $V_3$ whose output drives the power stage $V_4$. $V_5$ is an oscillator supplying 1000-cycle voltages to the bridge and to the plates of $V_3$. The amplifier is stabilized by the use of negative feed-back through $C_9$ and $R_6$, and the plentiful employment of bypass capacitors. Rectifier $V_6$ supplies the power stage, amplifier and oscillator.

### HIGH-SPEED RADIATION PYROMETRY

In the strip mill, one found some time back a "Speedomax" and a thermocouple receiver, used as a radiation pyrometer. While a discussion of this type of radiation receiver is outside the scope of electronics, the use of the photovoltaic cell or blocking-layer cell as part of a radiation pyrometer, is within it. A well-known type is the "Photronic" cell, which Weston occasionally calls a "dry-disk photocell."

The characteristics of this photocell which influence its use in pyrometry are (1) spectral sensitivity similar to that of the human eye, (2) rapid response to radiation, (3) a useful degree of stability, far above that of the phototubes, and (4) reproducibility. Such photocells are more nearly alike as to spectral response than as to total response. *(Concluded on page 496)*

# ELECTRON TUBES—Their Principles and Their Instrumentation Applications

By ANDREW W. KRAMER, Managing Editor, *Power Plant Engineering*, Chicago, Ill.

## XXIII. TUBES AND THEIR CLASSIFICATION

In 1920, slightly more than two decades ago, there was virtually only one type of thermionic tube in commercial use. This was the simple triode, used primarily in telephone work and in the simple wireless telegraph and telephone receiving and transmitting sets of the day. It was made in only a few sizes and was rather fragile in its construction; it was easily damaged and not always stable in its performance.

It is difficult to give with any degree of accuracy the number of types of tubes available today but in the current edition (1944) of the American Radio Relay League, Radio Amateur's Handbook, there are listed almost 800 different types of electron tubes! This, as nothing else can, indicates the astonishing progress made in our knowledge of and application of electronics. Today there are available tubes in every variety of size and for every conceivable purpose. There are small tubes, large tubes, glass tubes, metal tubes, air cooled tubes, water cooled tubes, high vacuum tubes, gas filled tubes, phototubes, cathode ray tubes, mercury pool tubes, cold cathode tubes—tubes ranging in size all the way from the FP 54, capable of measuring a flow of 60 electrons per second to water cooled giants such as the AW 220 which can dissipate 125 *kilowatts* at the plate at normal rating. In short, there are no end of tubes.

The price of the standard 01 A amplifier tube in 1921 was $7.00. Today this tube is listed at 33 cents and until all tubes for civilian use became scarce, one could shop around and buy them for even less in the so-called drug stores, and at lunch and cigar counters for even less. Many of the standard receiving tubes retail for less than a dollar.

Until about ten years ago, all tubes except the water-cooled units used for high-power radio transmitters were made of glass. Today tubes, even in the smallest size, are made either of glass or of metal and all tubes whether of glass or metal are rugged enough to withstand almost any industrial application. This has been true for at least a decade but it is only since the war that industrial engineers are beginning to accept the electron tube's ruggedness.

The tremendous number of tubes available today is likely to appall the neophyte in electronics who wants to pick out the most suitable tube for a particular purpose. Apart from their number available, many tubes have quite similar characteristics and unless one is more or less familiar with the particular advantages or limitations of certain tubes, the abundance of types available is likely to be more of a detriment than an advantage.

In this article, therefore, we shall consider, somewhat informally, the various types of tubes available and the methods by which they are classified. The situation is not as complicated as it appears. True, there are a large number of tubes available but there is a great deal of duplication between different cathode-voltage groups so that actually there are not as many different kinds of tubes as might appear from a first impression of tube listings. For example, the 01 A triode amplifier which was one of the first tubes to go into standard commercial production, has a filament cathode operating at 5 volts, a plate voltage of 90 to 135 volts, a grid bias of –4.5 to –9.0 volts and a mutual conductance of around 110 micromhos. Close inspection of tube data tables will reveal that there is another tube available with practically the same characteristics except that the filament voltage instead of 5 volts is 2.0 volts. This is the type 30. In other words, the 30 is the counterpart of the 01 A in the 2-volt battery tube classification.

Further inspection of the tube data tables will show that there is still another tube available with the identical characteristics of the 30. This is the 1H4G, a 2-volt battery tube with an octal base.

To one whose knowledge of electron tubes is based largely upon what has been published in these articles, all this, no doubt, is very mystifying; octal bases, mutual conductance, cathode-voltage groups, battery tubes, etc., what is the meaning of all these terms? Very few of these terms have been covered thus far, but they are easily explained.

The classifications of tubes as they exist today are not perfect but in the nature of things they are not bad and considering the rapid development of the art, the standardization is quite remarkable. Whatever lack of standardization exists today is due only to the extremely rapid development of the art.

Neglecting those early tubes which were built for relatively high power radio transmitting purposes, practically all of the first tubes had a simple filament cathode operating at 5 volts. This was approximately the voltage of the average storage battery. Shortly afterwards a few tubes were developed with filament voltages of 3.3 volts, suitable for operation from two dry cells. All these tubes were suitable for use only with a direct-current filament supply and they were all of the directly-heated cathode type, that is, the filament itself was the cathode.

The next development was the alternating-current type of tube, tubes capable of being operated from an alternating-current filament supply. For this, with directly-heated cathodes, a low filament voltage was necessary, and so, a line of 2.5-volt tubes was developed.

As explained in an earlier article* cathodes are of two types, directly or indirectly heated. When directly heated cathodes are operated on alternating current, the cycle variation of the current and voltage causes electrostatic and electromagnetic effects which vary the plate current of the tube at the supply frequency (in most cases 60 cycles) and thus produce a hum in the output when used in radio-receiver circuits. The electrostatic and electromagnetic variations are reduced at lower voltages and so the first so-called a-c. tubes had directly-heated filaments operating on 2.5 volts. A more effective way of reducing the hum, however, is by the use of an indirectly-heated cathode, consisting of a thin metal sleeve or thimble, coated with electron emitting material enclosing a tungsten wire which acts as a heater. The heater brings the cathode thimble to the proper temperature to cause electron emission. This type of cathode is also known as the equipotential cathode, since all parts are at the same potential. Ordinarily, the cathode is not electrically connected to the heater inside the tube, the terminals of the two parts being brought out to separate base pins.

The development of the indirectly-heated cathode, or heater type cathode as it is known, eliminated the necessity for low filament voltages, and most of the tubes using this form of cathode were designed for use with a 6.3-volt filament supply. Today, except for a few special types, practically all radio receivers are constructed for operation from alternating current using tubes having 6.3-volt cathode ratings, this voltage being regarded as standard. There is also available a standard line of battery tubes for operation at 2 volts. Nearly all of these have directly-heated cathodes.

In recent years tubes with filament voltages of 12, 25, 35 and even 50 volts have made their appearance. They are widely used in the small, miget type, transformerless radio receivers. They are wired in series so that all the tubes in a set will have a total voltage drop of 110 or 115 volts and thus, they can be operated directly from the 110-volt supply lines without the use of separate filament transformers.

*June 1943.

*(Continued on page 492)*

# PRACTICAL COLOR PHOTOPTOMETRY

By RAYMOND JONNARD, The Warner Institute for Therapeutic Research, New York, N. Y.

GRETHER[1] has recently published a "simple three-color mixer using filtered colors." The principle of this instrument is almost identical with that of the more elaborate apparatus which Jonnard and Escher-Desrivières described[2] in 1937. In view of the great practical interest of correct photoptometric determinations with colored lights, it seems pertinent to elaborate upon operational details which, in the light of modern investigation, have assumed an increasing importance. Perhaps the best conditions to be realized in any investigation involving color mixing problems can be derived from an expression of Newton's color mixing laws given by Grassman[3] in 1853:

(*a*) "If in a mixture one component is continuously altered, the appearance of the mixture will continuously alter," (*b*) "proportional increase of intensity of each component does not destroy the match at least in a definite region of the spectrum" (above 5500 A.u.), (*c*) "every mixture of light can be matched by a definite spectral light or a definite purple mixture which is mixed with a definite amount of white light."

These laws are complemented by Bruchner's observation[4] that the apparent brightness of a mixture of lights is not equal to the sum of its components, provided that the macular pigmentation of the observer does not disturb the measurements (particularly above 4800 A.u.). This last source of interference was studied by Krarup.[5]

In accordance with the foregoing considerations, the apparatus was provided with devices permitting the adjustment of the brightness of the observation area without changing the spectral composition of the color mixture *formed on this area.* Since the spatial distribution of the spectrophotometric absorption coefficients of opal glass is not uniform, this condition required the construction of a special adjusting diaphragm (which cannot be adequately described here). The side knob visible in the accompanying photograph was used for the adjustment of the intensity whose relative value was read on a positioning scale at the top of the instrument. Four other knobs located on the opposite side were used for the adjustment of the three-color composition of the light and for its saturation. Relative scales were provided for these parameters. Since the spectrophotometric characteristics of the color filter combination used were known, both the color composition and the level of illumination realized on the utilization area could be directly obtained by reference to a pre-established table. This instrument thus afforded a convenient means of studying the influence of intensity upon the sensation of saturation. This influence is for Parsons[6] "a physiological fact of immense importance."

Two other important features of such an instrument, which are often overlooked, are the uniformity of luminosity of the utilization screen in all azimuths, and the advantages of a large utilization area. (The diameter of the utilization screen was 5".) For all levels comprised between 0 and 0.2 footcandle the uniformity of luminosity was better than 1 in 1000 (as determined with a precision photoelectric photometer), and the instrument could be utilized in a zone circumscribed by a 75° angle around the axis, thus being suited for lecture demonstrations. The large uniformly bright area was found useful as a secondary calibrated nonglaring light source for both chromatic and achromatic scotopic adaptation, in connection with studies of aviation signals discrimination, detection of vitamin deficiencies, etc. When used for pupillometric measurements (in connection with a photographic method), it enabled us to carry the determination of the pupil area *vs.* intensity of light up to 10,000 lux, with various colored combinations, thereby elegantly completing the curves of Holladay and of Barnister and Hartridge.[7]

The large utilization screen found another use as an adjustable lighted background for optotypes of the split ring or Landolt type, which we used in (unpublished) studies dealing with simultaneous contrast visibility. Here the arrangement realized permitted to change the *sign* of the contrast *during the experiment.* It will be recalled that the visual acuity, depending upon the contrast of the test-object, is always influenced by both the color and saturation of the light used, as originally observed by Celsius in 1735.

The instrument was also found useful for the study of recurring vision (alias: allied phenomenon of Purkinje and of Davis,[9] Bidwell's ghost,[10] Hamaker's satellite,[11] following image of von Kries,[12] etc.). This phenomenon, the modern "after-image," is very complex and involves as many as seven well-defined phases, in varying sequence, all influenced by the state of light-or-dark-adaptation, the color, intensity and saturation of the light, the duration of the stimulus, the shape of the test-object and, as we found, the

*(Continued on page 500)*

(1) Walter F. Grether. A simple Three-color Mixer Using Filtered Colors. *Science,* Vol. 98, Sept. 10, 1943, page 248.

(2) Raymond Jonnard and Jean Escher-Desrivières. L'Eblouissement. 1 vol. Hermann, Paris, 1937.

(3) H. Grassman. Zur Theorie der Farbenmischung. *Annalen der Physik und Chemie,* 3rd series, Vol. 89, 1853, pages 69-84.

(4) Arthur Bruckner. Helligkeitsbestimmungen farbiger Papiere. *Archiv fur die gesammte Physiologie des Menschen und des Thiere,* Vol. 98, 1903, pages 90-129.

(5) Herdis Krarup. Physisch-ophtalmologische Grenzprobleme ein Beitrag zur Farbenlehre. Thieme, Leipzig, 1906. Page 100.

(6) John Herbert Parsons. An Introduction to the Study of Colour Vision. Cambridge Univ. Press, 1915. Page 29.

(7) Robert Faillie, Raymond Jonnard, and Henri Vial de Sachy. Variation de la Construction Pupillaire avec l'Eclairement. *Comptes Rendus Hebdomadaires de l'Académie des Sciences.* Vol. 199, July 2, 1934, pages 89-91.

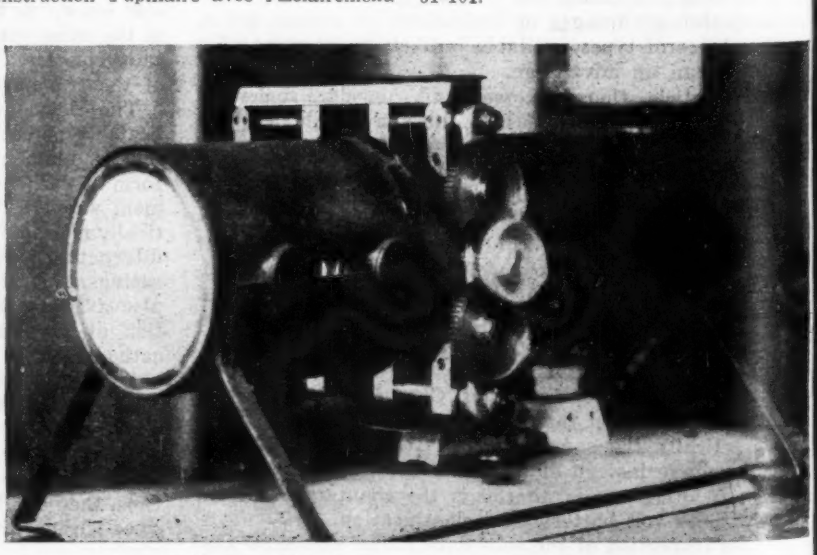
(8) Johann Evangelista Purkinje. Beitrage zur Kenntniss des Sehens in subjectiver Hinsicht. Reimer, Berlin, 1825/26. Vol. 2, page 110.

(9) A. S. Davis. On Recurrent Vision. *London, Edinburgh and Dublin Philosophical Magazine and Journal of Science.* 4th series, Vol. 44 (supplement), 1872, pages 526-530.

(10) Shelford Bidwell. On the Recurrent Images Following Visual Impressions. *Proceedings of the Royal Society of London,* Vol. 56, June 7, 1894, pages 132-145.

(11) H. G. Hamaker. Ueber Nachbilder nach momentaner Helligkeit. *Zeitschrift fuer Psychologie und Physiologie der Sinnesorgane,* Vol. 21, 1899, pages 1-44.

(12) von Kries. Uber die Wirkung Kurzdauernder Lichtreize auf das Seorgan. *Zeitschrift fuer Psychologie und Physiologie der Sinnesorgane.* Vol. 12, 1896, pages 81-101.



Large Trichromatic Photoptometer of Jonnard and Escher-Desrivieres.

# ELECTRIC GAGING METHODS
## for Strain, Movement, Pressure and Vibration

By HOWARD C. ROBERTS, University of Illinois

### IV. GAGING METHODS BASED ON VARIATIONS OF INDUCTANCE

*(Concluded)*

#### §10. Sensitivity

As with other electric gaging systems, the sensitivity of a complete magnetic gaging system depends largely upon the sensitivity of the indicating or recording instrument. For static measurements, instruments having extremely high current sensitivity can be employed, and there is no difficulty in providing stable magnifications of 100,000, or higher. With such a system, measurements can be made to microinches with equipment rugged enough for shop or factory use. This sensitivity can easily be increased tenfold in laboratory surroundings.

If a system employing electronic amplification is constructed, disturbances caused by the transient vibrations of the building limit the sensitivity that can be employed for static measurements; for dynamic measurements the ambient vibrations impose the usable limit of sensitivity, since their effects cannot be filtered out without affecting accuracy.

EDITOR'S NOTE

These diagrams are reprinted (from last month's instalment) for the convenience of our busy readers.

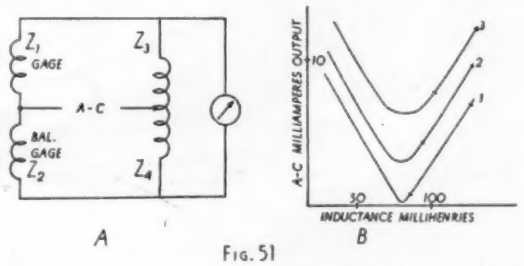



FIG. 51

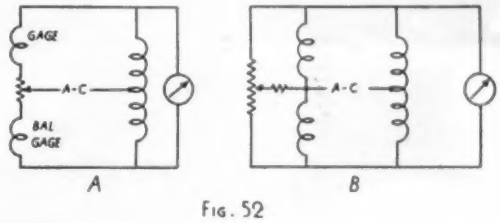



FIG. 52

The most sensitive circuits are the bridge types; with some of the bucking-type circuits nearly as sensitive.

The sensitivity of a bridge circuit (change of output current versus change in inductance of gage) is greatest when certain design requirements are fulfilled. If the center-tapped inductor (Fig. 51A) has low resistance and negligible leakage inductance, then all circuit parameters excepting the exciting voltage and the impedance of the indicating instrument are ordinarily fixed by the physical limitations of the equipment. The exciting voltage is limited by the magnetic characteristics of the core material, since too high a voltage will cause saturation and consequent distortion of the gage characteristic.

The impedance of the indicating device, however, can be controlled to some extent. Such instruments ordinarily have some inductance, and it is simple to introduce capacitance in series until the inductive and capacitative reactances are equal (at the frequency of excitation); the impedance of that branch of the circuit is then approximately equal to the ohmic resistance of the instrument. The output current may by this expedient be increased several hundred percent;[137] the method is effective with dynamometer-type instruments or with rectifier-type d-c. instruments.

The instruments employed with inductance-type gaging circuits must be a-c. instruments; if d-c. instruments are preferred, suitable devices must be employed to convert the alternating to direct current. Such devices may be thermocouples, rectifiers, or electronic amplifiers. Dry-disk rectifiers are widely used; they are compact, rugged, and have low impedance in normal operation. The impedance of such a rectifier is much higher for small currents than for large, so that in bridge-type circuits the sensitivity of the indicating instrument is made least at the point of balance—just where greatest sensitivity is needed. Circuits have been developed and are in use which apply polarizing voltages to the rectifier elements at all times, so that in operation the rectifier is kept in the most favorable portion of its operating range. Some of these circuits likewise provide phase-sensitivity, and can therefore indicate direction as well as magnitude of bridge unbalance.[104, 138] Many of the bucking-type circuits have similar properties.

In the bridge-type circuits (Fig. 52) provision of the facility for resistance balance has the effect of increasing the sensitivity of the system. The effect of resistance unbalance is shown in Fig. 51B. Although away from the point of inductive balance all three curves have the same slope, curve number 1 is the only one which does not involve a relatively large output current even at the point of inductive balance. As a means of indicating direction of unbalance as well as magnitude, these circuits are employed with an initial unbalance (sometimes called "offset"), so that a change in one direction will decrease the deflection, while a change in the other direction will increase it. Obviously the smaller the standing current, the more sensitive the indicating instrument may be. The range of operation for each of the three curves is indicated in the drawing. It may be noted that the indicated range is in that portion of the curve which describes the increasing (beyond the balance point) inductance of the gaging element. This means that the air-gap of the gaging element is less than that of its companion balancing element; it is operating on the "closing" side of the curve. Sensitivity is increased as the air-gap is decreased.

Certain refinements in the design of gaging elements will increase their sensitivity. Low ohmic resistance together with relatively high impedance (high "Q") makes for an efficient circuit. High frequencies of excitation make the effective impedances higher. Too high an exciting frequency, however, introduces difficulty in connecting cables and causes iron losses in the cores of the inductors. The air gaps should be as small as practicable, but care must be taken that they never close in operation. Short air-gaps increase sensitivity in two ways—by increasing the inductance, and by providing a larger percentage change in inductance for a given change in air-gap. In practice, the variable-inductance gaging element is operated on the "opening side" of the curve if it is to experience tension only, or on the "closing side" if the strains are to be compressional. The standing current may be made smallest thus; adjustment of the circuit is made easier, and the recording device is made to operate more efficiently.

#### §11. Stability

If properly designed, variable-inductance gages are inherently extremely stable. In nearly all cases, instability in such a circuit will be found in one of the associated devices, or in the mechanical installation itself, rather than in the primary element.

*(Continued on page 484)*

(137) B. F. Langer. Design and Applications of a Magnetic Strain Gage. *Proceedings of the Society for Experimental Stress Analysis*, Vol. 1, No. 2, 1943, pages 82-89.

(138) R. J. Cox. A Note on Electromagnetic Induction Micrometers. *Journal of Scientific Instruments*. (London), Vol. 19, 1942, pages 117-120.

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# TORQUE and THRUST MEASUREMENTS on Small Aircraft Engine Test Stands

By J. LISTON, Assoc. Professor of Aeronautical Engineering, and C. E. SCHAEFER* Ass't Instructor in Aeronautical Engineering, Purdue University, Lafayette, Indiana.

THE rapid expansion of the aircraft engine industry in recent years has been accompanied by an increasing need for engineers familiar with the ground testing of aircraft engines. To help fill this technical need, Purdue University has been gradually enlarging its instruction facilities in the form of an aircraft engine laboratory planned primarily for engineering student instruction.

Torque stand facilities in this laboratory are rather completely equipped with up-to-date instruments and testing devices quite similar to, and in many cases the same as, units found in industrial and government laboratories. Stand No. 1, Fig. 1**, which is used for routine instruction of Aeronautical and Mechanical Engineering students, is designed to handle air-cooled engines up to 400 or 500 horsepower. It consists of a U-shaped reinforced concrete test cell with an adjacent control room large enough to accommodate groups of students. The engine is mounted on the end of a heavy hollow steel shaft which is supported fore and aft by heavy double-row self-aligning ball bearings. Loads on these bearings are transferred to a large steel cylinder supported on conventional cable mountings. All control and gage lines between the engine and the control room are flexible, thus permitting some movement of the engine without affecting control settings or instrument readings. In general, the stand is equipped to duplicate the facilities of larger industrial and government stands but special attention has been given to careful identification of all instruments and controls, and the arrangement was planned for use by inexperienced student operators.

In the larger sizes of aircraft engines, increasing use is being made of built-in torquemeters for power measurements on the ground as well as in flight. However, to date few small engines of the size best suited to beginning student instruction are equipped with such devices. Hence, an alternate means for measuring engine torque was incorporated in the initial design.

This device, Fig. 2, consists of a reaction torque arm attached to the floating shaft which supports the engine.

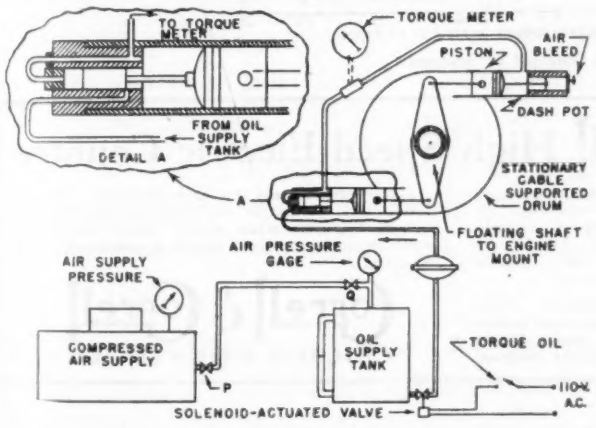


Fig. 2. Original Arrangement for Measuring the Reaction Torque.

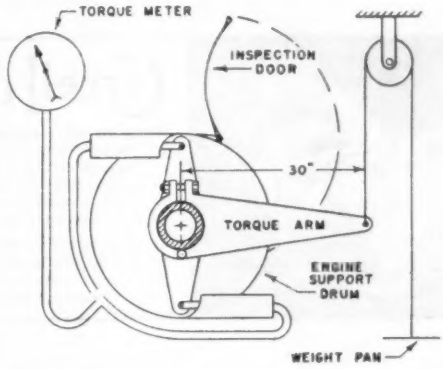


Fig. 3. Arrangement for Calibrating the Torquemeter.

The torque reaction is taken by two pistons, one of which is attached to a dash-pot and the other to a metering valve which allows only sufficient oil to enter to keep the pistons floating near mid-position. Air pressure greater than the maximum pressure in the torque cylinders is used to maintain a continuous supply of oil.

The torquemeter gage is a Bourdon tube type of pressure gage, and for calibration, the arrangement shown in Fig. 3 is used. A typical student calibration curve is shown in Fig. 4 (A). This calibration may be used directly during tests and the horsepower may be determined from

$$\text{BHP} = \frac{2\pi N Q}{33{,}000}$$

where $N$ = engine r.p.m.
and $Q$ = torque in lb.-ft.

This torquemeter has been in regular student use for two

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**Fig. 1 of this article, showing the main control panel of Torque Test Stand No. 1 in the Purdue University Aircraft Engine Laboratory, appears as the cover photo of this issue.—EDITOR.

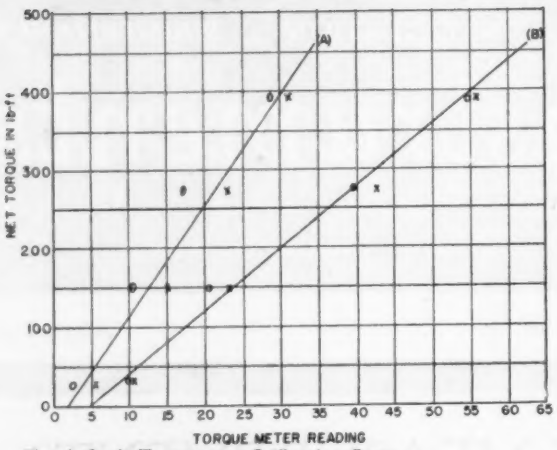



Fig. 4. Static Torquemeter Calibration Curves
(A) Original Torquemeter. (O) Increasing Load
(B) Metallic Bellows Type. (X) Decreasing Load

years and has proved to be reasonably satisfactory and reliable. The torque cylinders were not surface-hardened; and they have suffered some wear, with resultant increased leakage by the pistons, but the oil supply has proved adequate to offset the effects. However, it was felt that eventually the leakage would become excessive, so a modified arrangement that would eliminate all sliding fits was designed and built.

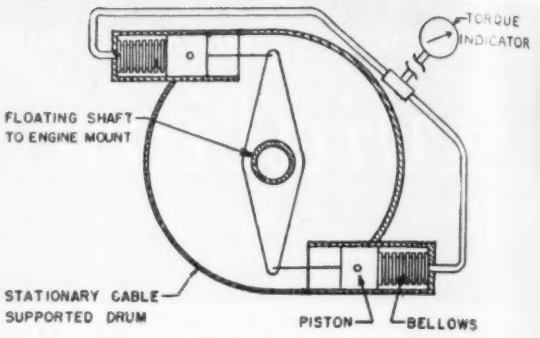



Fig. 5. Modified Arrangement for Measuring the Reaction Torque.

This new torquemeter, Fig. 5, consists of metallic bellows filled with oil and fastened in place in the torque cylinders. Torque forces on the bellows are transferred hydraulically to the Bourdon tube in the torque indicating gage. This bellows type torquemeter is a closed system and all leakage has been eliminated. Calibration of the torquemeter is shown in Fig. 4 (B).

Preliminary experience with this torquemeter is favorable but the life of the bellows units has not been estab-

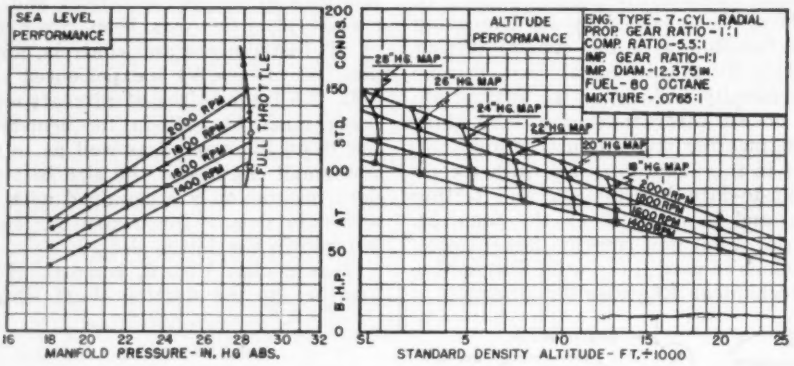
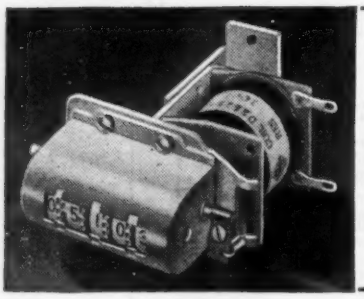



Fig. 6. Typical Test Results Obtained by Students.

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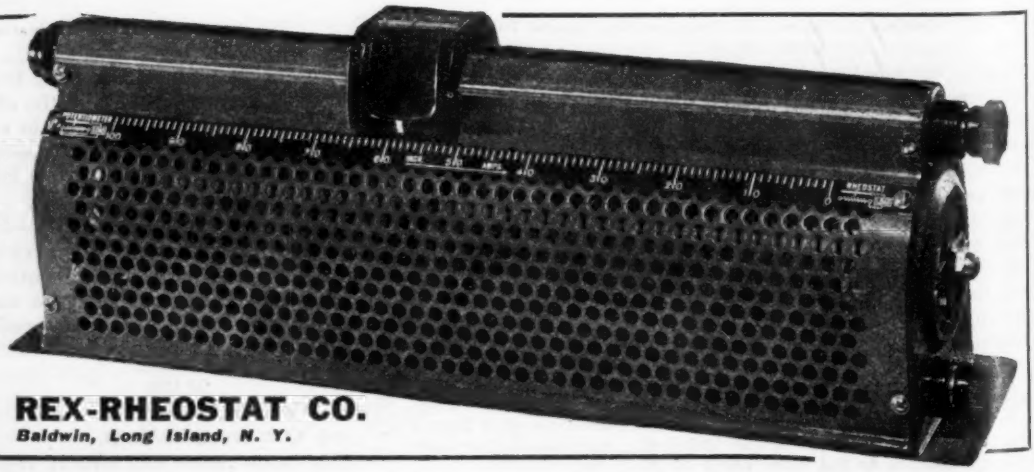

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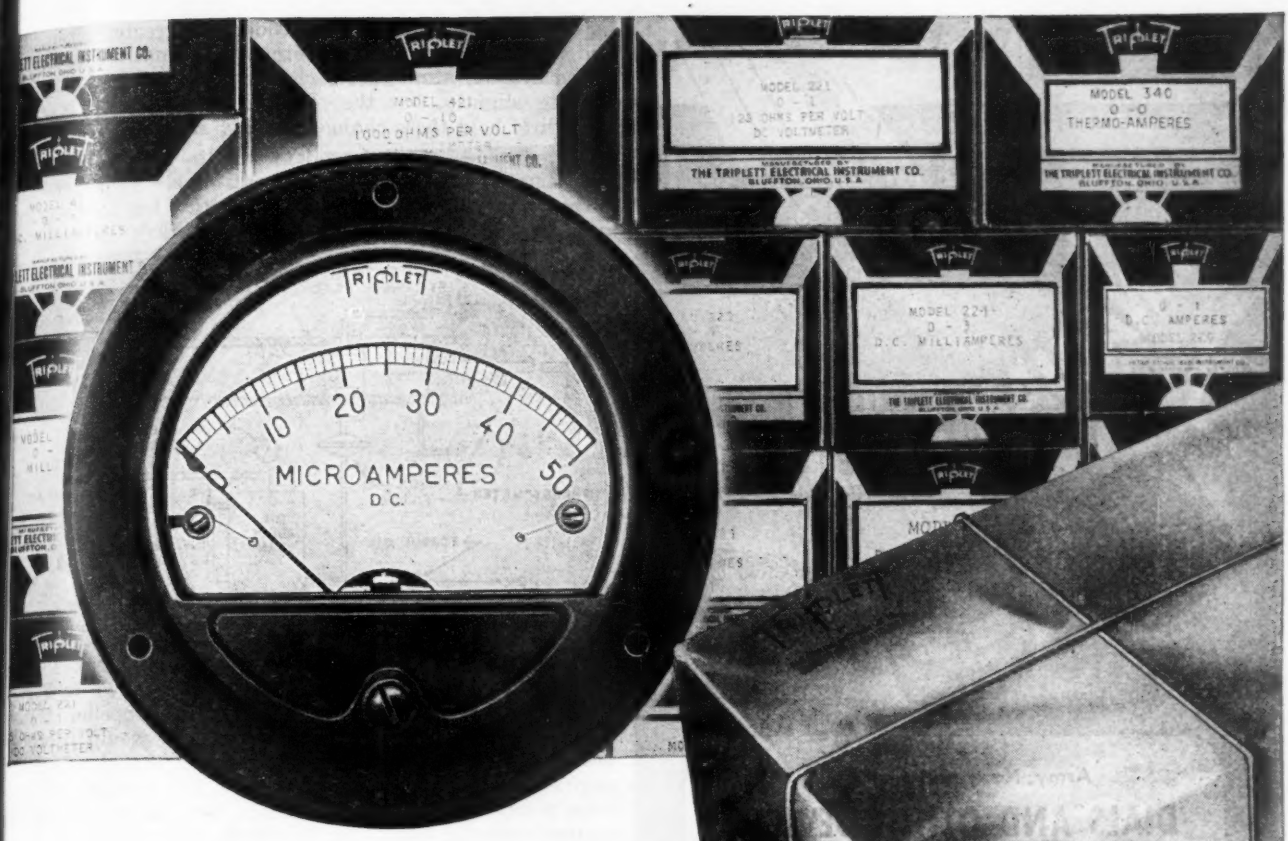


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lished. The instrument has considerably greater sensitivity and reacts more rapidly to torque variations. Since it is a closed system, atmospheric changes affect the initial gage reading slightly, but the enclosed volume of oil is great enough to hold these changes to very small values.

Fig. 6 shows typical student results from a 530-cubic-inch engine equipped with a controllable propeller. The horsepower values were obtained with this torquemeter, and they check the engine manufacturer's data rather closely.

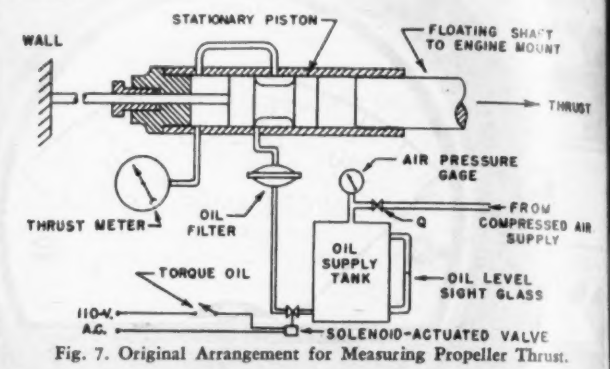


Fig. 7. Original Arrangement for Measuring Propeller Thrust.

When the original plans for torque stand No. 1 were drawn, the thrust-measuring arrangement shown in Fig. 7 was incorporated. It was realized that propeller thrust measurements inside a U-shaped test cell would probably not correlate well with static propeller thrust when the engine was mounted on the airplane. But it was felt that some worthwhile information might be obtained, hence the system shown in Fig. 7 was included.

This method looked promising but it was unsatisfactory

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Regardless of the criticism this article may receive, I have used this method successfully for more than fifteen years, in repairing high-grade railroad watches by which the Panama R.R. trains were run, also ship's chronometers used on vessels without radio receiving sets. Many of the timepieces were returned to me regularly over a period of years, so I know that a coating of oil when properly applied does not interfere with the accuracy of a timepiece in any climate, that it does retard rust, eliminates the necessity of replacing many parts, prolongs the period of time between overhauls and greatly increases the life of the instrument.

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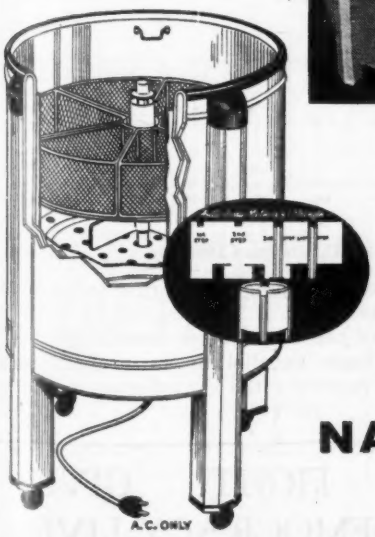


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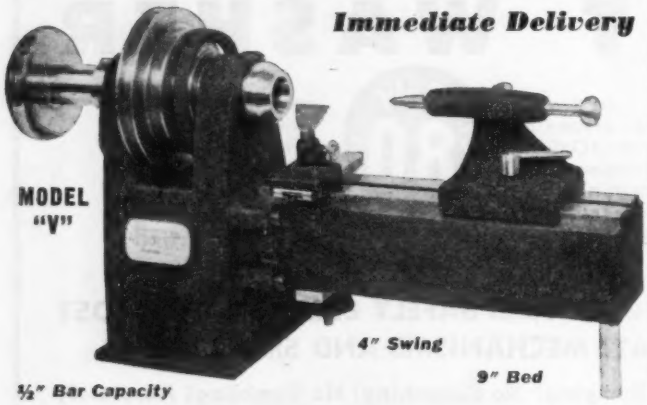


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—chiefly because of the large initial coefficient of friction on the floating shaft. Some results were obtained, but little reliance could be placed on the accuracy.

The rod connecting this thrustmeter to the rear wall of the test pit was then replaced with a cable; and a cable tension type of thrustmeter, Fig. 8, was designed and built.

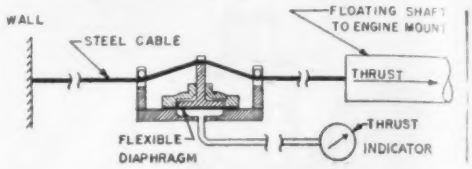


Fig. 8. Cable Tension Type of Thrustmeter.

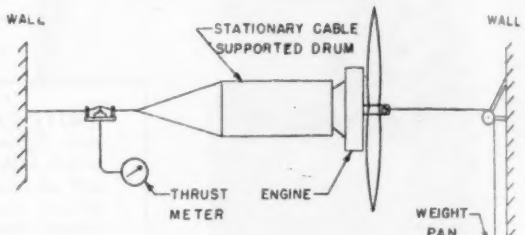


Fig. 9. Arrangement for Calibrating the Thrustmeter.

The supporting cables for the engine mount are anchored on stacks of rubber disks in the walls and floor of the test pit. Hence, the entire test assembly moves forward slightly with increasing thrust. This deflection proved just sufficient for the cable tension thrustmeter, and the system proved

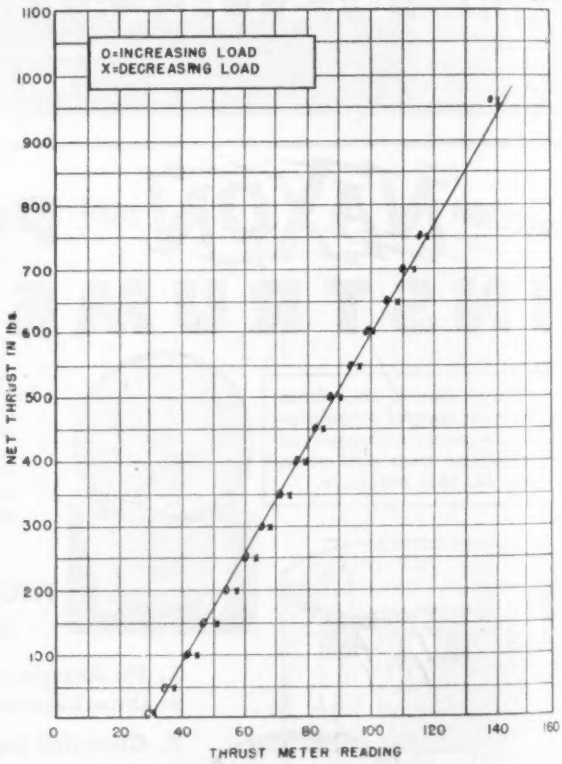


Fig. 10. Thrustmeter Calibration.

quite sensitive. Without damping, the thrust indicator will show surging in the test pit.

Static calibration of the thrustmeter is accomplished by applying increment loads parallel to the propeller shaft, Fig. 9. A calibration curve for the thrustmeter is shown in Fig. 10.

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## ELECTRIC GAGING METHODS

*(Continued from page 275)*

The prime requirement of a variable-inductance gaging element is that the inductance of the element (or the ratio of two inductances) should vary in a consistent and predictable manner with the change in air-gap or in armature position. It is of little importance whether or not the ohmic resistance is also changed, since such a change will be small. In a well-designed circuit the ohmic resistance is small compared to the total impedance, and the circuit is compensated for the change.

In general, the series-type circuit is not desirable for measurements in which high accuracy and stability are required, although systems employing the circuit can be made both accurate and stable. They are usually employed in applications in which a relatively large magnitude is being measured—so large that low instrument sensitivity is required. For measurements of small magnitudes at high accuracy, the bridge circuits are desirable; some of the bucking-type circuits are also satisfactory.

It is not practical to construct gaging elements in which no change in ohmic resistance or in inductance will occur with change in temperature: it is possible, but prohibitively expensive. The methods which must be employed to produce these conditions usually lower the efficiency of the gage to such an extent that the over-all performance often shows a net loss. For applications at ordinary temperatures, gages are designed to be mechanically robust, the coils are wound with copper wire, and the cores are usually made of laminated silicon steel. (High-permeability alloys are occasionally used.) No special precautions are taken to reduce the temperature coefficient of resistance. In such a gaging element there will be a change in resistance with temperature, and also a change in inductance. These changes are caused by changes in dimensions of the gage parts, and by changes in electrical and magnetic characteristics of the metals with temperature. For one set of dimensions, and one type of application, these changes can be made to counteract; but for any other set of conditions that compensation will fail. One must expect, therefore, a change in resistance and in inductance of an inductance-type gaging element when the temperature changes.

Installation of a balancing or compensating gage close to the measuring gage, or the use of the inductance-ratio gaging element, will provide almost perfect compensation for these temperature effects. If widely varying temperatures are encountered, such a system will be found almost imperative.

The effect of changes in temperature upon the specimen has been described (in the discussion of capacitance-type gages). The same considerations apply to inductance-type gages; the principal point of difference arises because the material of magnetic gages is usually ferrous and its coefficient of thermal expansion may be difficult to match to that of the specimen. It is customary to install the magnetic core material in a frame or housing of other material, so that the effective coefficient of thermal expansion can be modified. Fortunately, however, the use of the inductance-ratio gaging element eliminates most of the drift originating in change of dimension of the gage; its two halves will experience the same changes, and each will compensate the changes in the other.

It is essential, as with all other electric gaging circuits, that the exciting voltage remain constant unless a null method is used. If a null method is used, change in exciting voltage will affect the sensitivity and the accuracy of the balancing process, but will not in any other manner affect sensitivity, stability, or accuracy of the bridge. Dynamic measurements in general require deflection-type methods; with them the voltage must be maintained constant, and often waveform and frequency likewise. It is an interesting fact that the sensitivity of a bridge-type gaging circuit is not always increased by increase in exciting voltage.

The source of the exciting current for variable-inductance gages imposes a problem almost as difficult as the gages themselves. Low-impedance gages often require several volt-amperes of electric energy; this amount varies with

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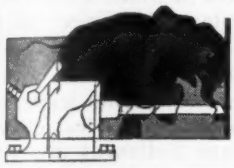

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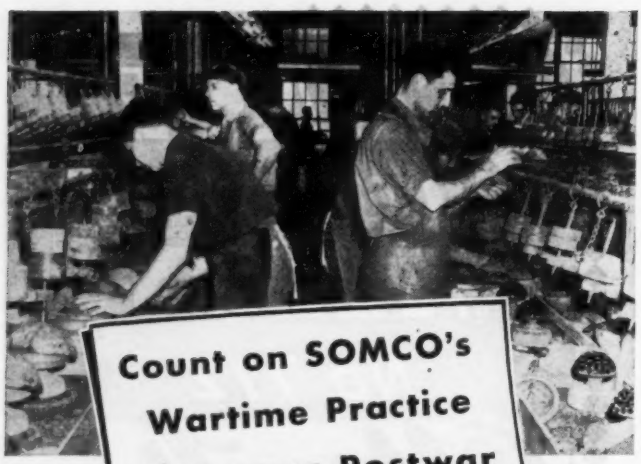

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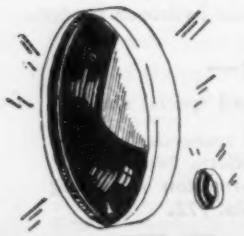

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applied strain, and the power factor of the circuit varies likewise. The generator used must be well regulated against changes in the demand of the gage circuits and against changes in the power operating it as well.

The accuracy of a deflection-type method or the sensitivity of a null method are affected by changes in the characteristics of the indicating instruments. Many instruments —especially a-c. instruments of high current sensitivity— are affected by temperature changes. This sort of instability is a function of the indicating instrument rather than of the gaging circuit proper; it will be discussed with those instruments and their characteristics. Changes in the rectifying devices will likewise be discussed in a later article.

The center-tapped inductor which forms the two fixed bridge arms will remain a fixed unity ratio throughout almost any change in working conditions; it suffers no drift if properly constructed.

In high-level variable-inductance gaging circuits—those which do not require amplifying devices—errors occasionally appear because of changes in the output circuits when those circuits are required to filter the rectified output current, to produce an output which can be recorded by the oscillograph. The design of these filters is an art within itself; it is described in many locations.[139] The principal requirements of such filters are these: the carrier must be as completely removed as possible; the modulating frequencies must be undisturbed by the filtering action; and the presence of the filter must not disturb either the bridge circuit or the indicating instrument. This last requirement is difficult to fulfill in those systems in which sensitivity is controlled by the addition of resistance in series with the indicating instrument.

### §12. Accuracy

The accuracy of variable-inductance gaging methods is affected by mechanical factors and by electrical disturbances. The mechanical factors are ordinarily the more difficult to control.

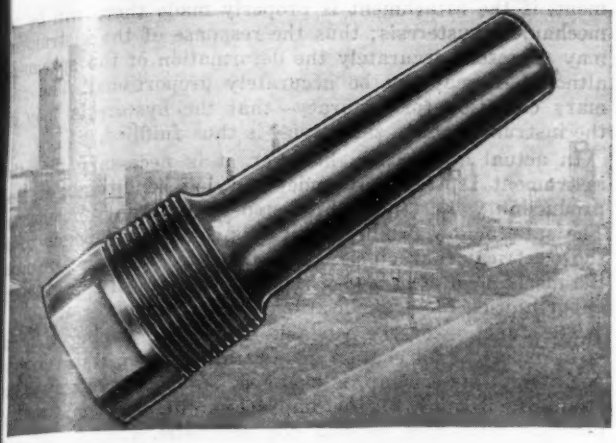
Just as with any other gage, whether it be electrical or mechanical, errors will be caused if the attachment is imperfect, if the material of the gage is subject to change in dimension, or if the construction of the gage is such as to permit either slippage of the gage on the specimen or mechanical hysteresis within the gage itself. These errors can be prevented only by the most careful mechanical design and construction.

In addition to these mechanical errors, however, an electric gaging system is also subject to certain errors of purely electrical character; the inductance-type gages are less subject to electrical difficulties than some others. Care in electrical design, care in construction and installation, and reasonable maintenance will eliminate nearly all of these sources of error. The inductance-type systems, if properly designed and operated, are capable of accuracy high enough to fit them for use in the gage departments of our best production organizations.

The bridge-type circuits, which are also among the most sensitive, are inherently the most accurate of the circuits used with inductance-type gages. The inductance-ratio type of primary element is inherently the most stable and the most accurate of the instruments embodying magnetic principles of operation. That does not mean that any bridge-type circuit is better than any circuit of one of the other types, nor that any inductance-ratio pick-up is better than all other types of pick-ups; it does mean that a bridge-type circuit, because of its fundamental principles, is the one which responds best to refinement, and that the same is true of an inductance-ratio pick-up because of the opportunities for good design which are offered by its basic principles of operation. Careful design will make any of the circuits described operate excellently; the same care in design will provide the most improvement in results if applied to the bridge-type circuit.

Many of the gaging elements described have no moving parts other than those attached to the specimen and moved by the elastic deformation of the material. In such an ele-

(139) W. E. Everitt, Communication Engineering, McGraw-Hill, 1937. 700 pages. Chapter 6.



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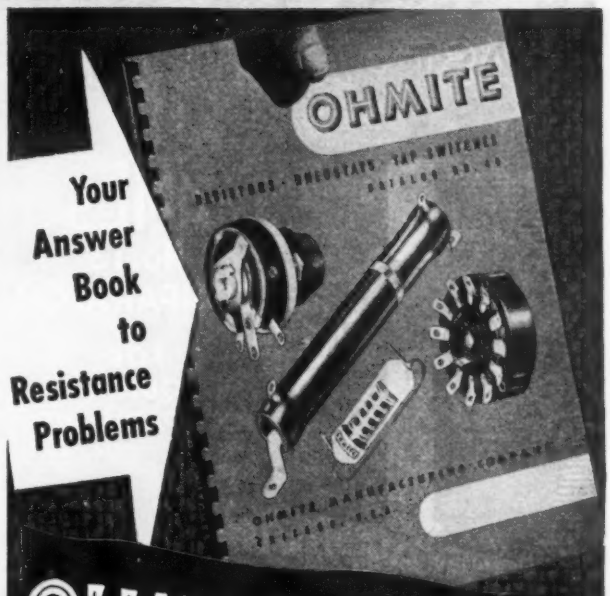


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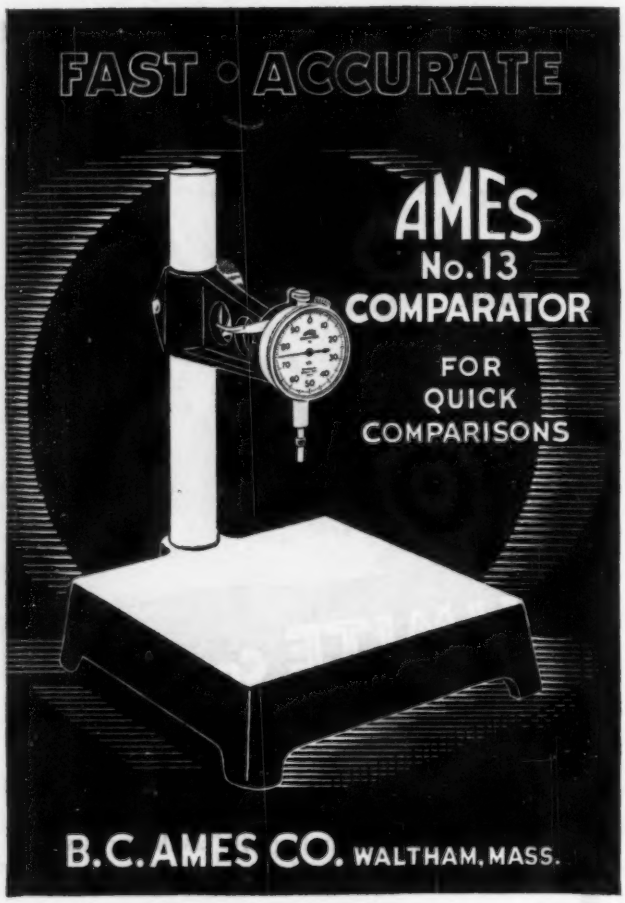


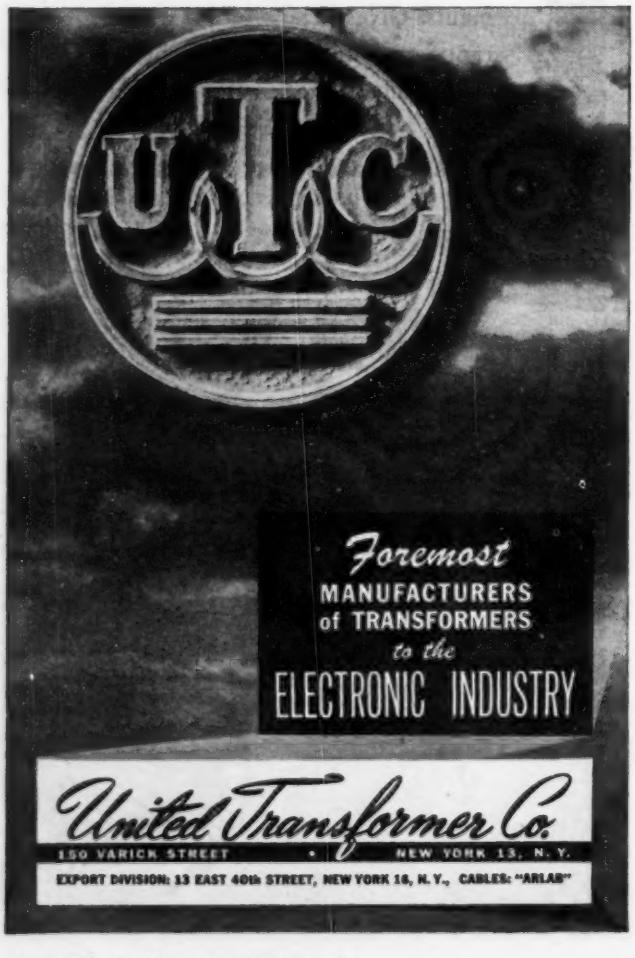


ment, if the attachment is properly made there will be no mechanical hysteresis; thus the response of the instrument may represent accurately the deformation of the specimen, although it may not be accurately proportional. The primary condition for accuracy—that the hysteresis loop of the instrument have zero area—is thus fulfilled.

In actual application, however, it is necessary that the instrument repeat itself under varying conditions; its reproducibility must not be affected by external phenomena. The satisfactory fulfillment of this condition depends upon the electrical characteristics of the gage as much as upon the mechanical. The bridge-type circuits afford the greatest opportunities for compensation.

The function of the variable-inductance gaging element is to experience a change in inductance when its armature position, or its air-gap, is changed, but not from any other stimulus. Because of the impracticability of constructing pick-ups with this perfect characteristic, the gaging devices in use employ elements which in operation experience other changes than those of inductance. It is necessary that these changes, if they cause an indication of the instrument, be compensated in some manner.

It has been pointed out that the ohmic resistance of the gage should be small, and that the capacitance between elements be small likewise (the capacitive reactance must be large). These factors then will play only a small part in the performance of the gaging circuit; small changes in them will have little importance.

If the inductance-ratio type element is used, or if the compensating gage is placed close to the measuring gage, the changes in ohmic resistance and in capacitance will be common to two adjacent arms of the bridge circuit, and will not affect the balance of that circuit. Changes in inductance caused by anything other than movement of the armature will likewise occur in these two arms of the bridge simultaneously. Changes in the bridge balance, therefore, will result only from changes in inductance caused by movement of the armature of the gage. No drift will be experienced. But these changes will change the total impedance of the circuit, and can therefore affect its sensitivity, or even its accuracy unless it is of the null type.

The errors resulting from these uncompensated changes are extremely small; they can ordinarily be ignored. For example, if the ohmic resistance of the gage is 2 ohms and its impedance 100 ohms (these are common values) a change in temperature of about 18°F. will cause a change in ohmic resistance of the gage of about 10%. This change in resistance will cause a change in impedance of the gage of about one-fifth of one percent. And this change in impedance will cause no greater error. It may be seen that changes in room temperature, and moderate changes in outdoors temperature, will cause small errors. Even so, their compensation can be accomplished if it is necessary. Such compensation may be provided by the use of wire having suitable temperature coefficient of resistivity,[111] and by the use of material for the winding spool which has a temperature coefficient of expansion equal to that of the wire. With constantan wire, the resistance of the coils can be made virtually unchanging at all normal temperatures.

In the same manner, by employing magnetic material which has a low temperature coefficient of permeability, the inductance can be made less changeable with changes in temperature. In order to make the inductance invariant, it is necessary to evaluate the changes due to the expansion of the core material with temperature, and the change in its magnetic permeability, and to correlate the two. This correlation can be made effective over limited ranges.

A simpler, less precise, but far more economical method is to install in series with the gaging element such compensating elements as are required. Temperature compensation for resistance is accomplished by adding series resistance elements which possess temperature coefficient opposite in sign to that of the gage. Temperature compensation for inductance requires the installation of series inductors having temperature coefficient opposite in sign to that of the gage; they can be small variable air-gap units whose armatures are moved in accordance with the change in tem-

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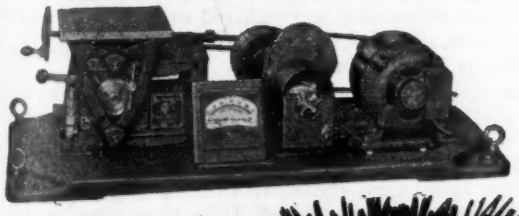

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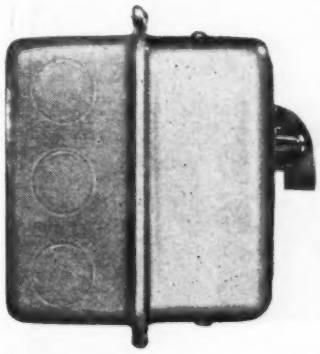

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perature.[140] Such compensation is not perfect, but is simple, economical, and sufficient for most uses. Even these methods are seldom required if inductance-ratio gaging elements are employed.

For most applications, the use of the inductance-ratio gaging element, or the compensating gage installed close to the specimen, will give satisfactory results. In work requiring extremely high precision it is advisable to incorporate compensation in the gage design. In some applications in which sudden and large changes in temperature occur (as in rolling mills) quite elaborate compensating systems have been used.[141] Even in ordinary installations, however, carelessness in operating procedure can introduce large errors.

Referring to Fig. 51B, the curves there may be considered as representing calibration curves for magnetic gaging circuits. Curve 1 is the most desirable form; it is almost perfectly linear from quite near the point of balance to a point corresponding to a current output of more than 10 milliamperes. But curves 2 and 3 are less desirable: a little distance away from the balance point they are like curve 1, while near the point of inductive balance they depart considerably from the straight line, and the current even at the point of inductive balance is several milliamperes. It is clear that of these three curves, only number 1 could be employed without constant checking to determine if it is the lack of a perfect resistance balance or the normal output of the gage which causes the high output current.

Again the use of the compensating gage solves the problem. If the compensating gage is employed, or if an inductance-ratio gaging element is used, the resistance balance, once obtained, will be maintained.

Only one principal source of error peculiar to the gaging circuit remains to be considered: it is the problem of calibrating the gage and then transferring it from the calibrating device to the work.

If an inductance-ratio gaging element is used, the problem is simple; the calibration curve for such a gage can be made quite linear for a considerable range. It is only necessary to calibrate the gage on a suitable device, then remove it, transfer it to the work, and there install it. The air gaps, or armature spacing, need be only approximately the same as during calibration. (Because of the mechanical construction, the sum of the two air gaps is a constant.) Since the output current is measured at intervals, and differences taken, no error will be introduced by small changes of spacing in installation.

If a variable-inductance gage is used, care must be taken in its installation, or the calibration will be lost in transferring the gage to the work. The gage is placed on the calibrating stand, adjusted to the desired characteristics, and at the same time the compensating gage is adjusted and its adjustments are locked. It is then possible to remove the working gage, place it in its operating location, and (without altering the adjustment of any other part of the system) adjust its air-gap or armature position until the circuit is again balanced. The calibration of the circuit is maintained by the compensating gage, which is unchanged, and by the two fixed arms of the bridge. The initial unbalance or "offset" (see §10) is then established and the gage is ready for use.

In all magnetic gages, the leakage inductance is large; this is an inevitable consequence of the presence of the air-gap. Because of this condition, the presence of large masses of metal near the air-gap can cause a change in the inductance of the gage. The calibrating stand used should be so constructed as to cause the same change as does the metal of the specimen. If protective metal covers are used, either on the gage or the balancing unit, they should be in place during the calibration process.

If these precautions are observed, the transfer of to gage from the calibrating stand to the working position should introduce no inaccuracy; it is assumed, of course, that if the gage is constructed in more than one piece a jig is employed to maintain alignment of parts during the transfer.

(140) R. R. Batcher Process Control Methods for Industrial Use. *Electronic Industries*, Vol. 3, 1944, pages 94-95, 198, 200, 202.
(141) U. S. Patent No. 2,276,816, Samuel Bagno.

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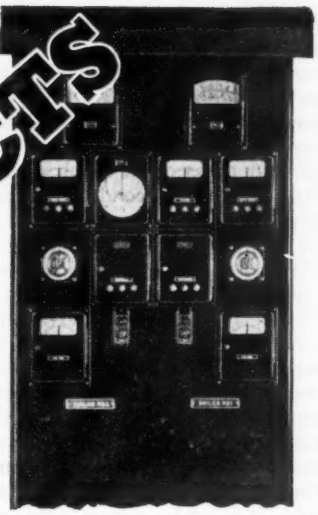

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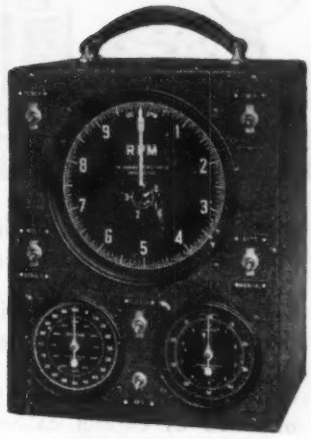


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## ELECTRON TUBE PRINCIPLES

*(Continued from page 473)*

The early glass tubes have been supplemented by a line of entirely metal tubes. These were made practical by advances in electrical welding methods which in themselves were brought about by the use of electron tubes to provide accurate control of the welding operations. In the manufacture of these metal tubes, vacuum-tight welds requiring current flows of as much as 75,000 amperes are made in a fraction of a second. Another factor contributing to the development of these tubes was the use of Fernico metal, an alloy which seals readily to certain special kinds of glass. The use of Fernico eyelets and glass bead seals, as illustrated in the cutaway drawing of a metal tube in Fig. 156, permits of many advantages in tube assembly.

The advantages of metal tubes probably lie mostly in manufacturing methods, although in certain applications the superior shielding afforded by the metal shell is an important factor. They are also more compact than glass tubes. From an industrial application standpoint however, metal tubes probably have an advantage over glass tubes that does not hold in the communication field. The electron tube, it must be remembered, was a baby born and nurtured in the communication field. The communication engineer has always been concerned with rather delicate apparatus, and the idea of a glass tube never held any misgivings for him. The industrial electrical engineer, accustomed to working with ponderous equipment, developed a shyness toward the use of tubes which persists to this day, though Heaven knows he used glass incandescent lamps with no inhibitions. It is in this respect that metal tubes have a distinct psychological advantage, even though they are only little more rugged than glass tubes. All metal tubes have heater cathodes operating at 6.3 volts.

It is evident now that while tubes can be classified according to their function, as rectifiers, or amplifiers or more accurately by the number of elements they contain, such as diodes, triodes, tetrodes, etc., another useful classification is obtained when they are grouped according to their filament or heater voltages and that is how they are classified most frequently. Thus, tubes will be grouped as 6.3-volt low-power tubes, 2.5 volt low-power tubes, 2-volt battery tubes, metal tubes, etc. Rectifiers and high-power tubes are usually grouped by themselves, as diodes, triodes and tetrodes. In the A. R. R. L. Radio Amateur's Handbook there are 26 such classifications.

As listed in the Wiley Electrical Engineers' Handbook, they are grouped in 19 classifications according to function. Thus Group I lists low-power high-vacuum rectifiers, a group which itself is diveded into half-wave and full-wave

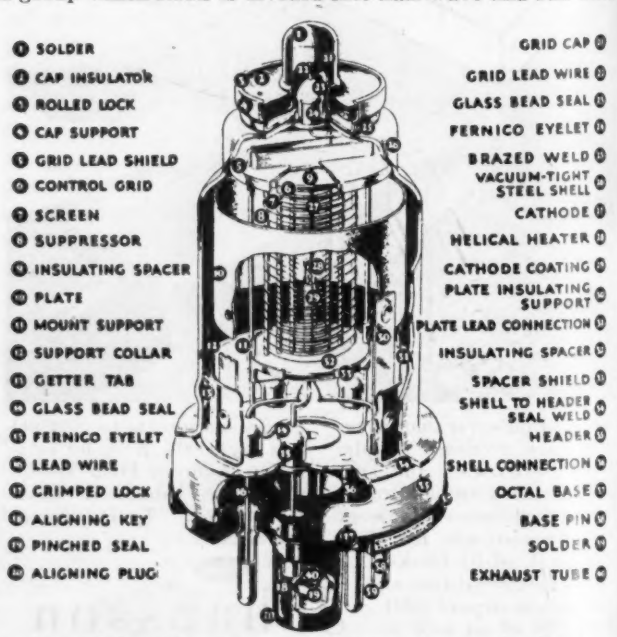


Fig. 156. Internal structure of an all-metal electron tube. Drawing courtesy R. C. A.)

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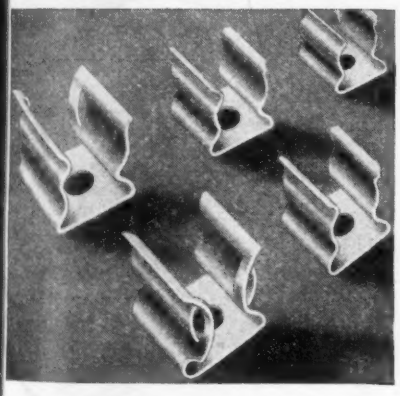

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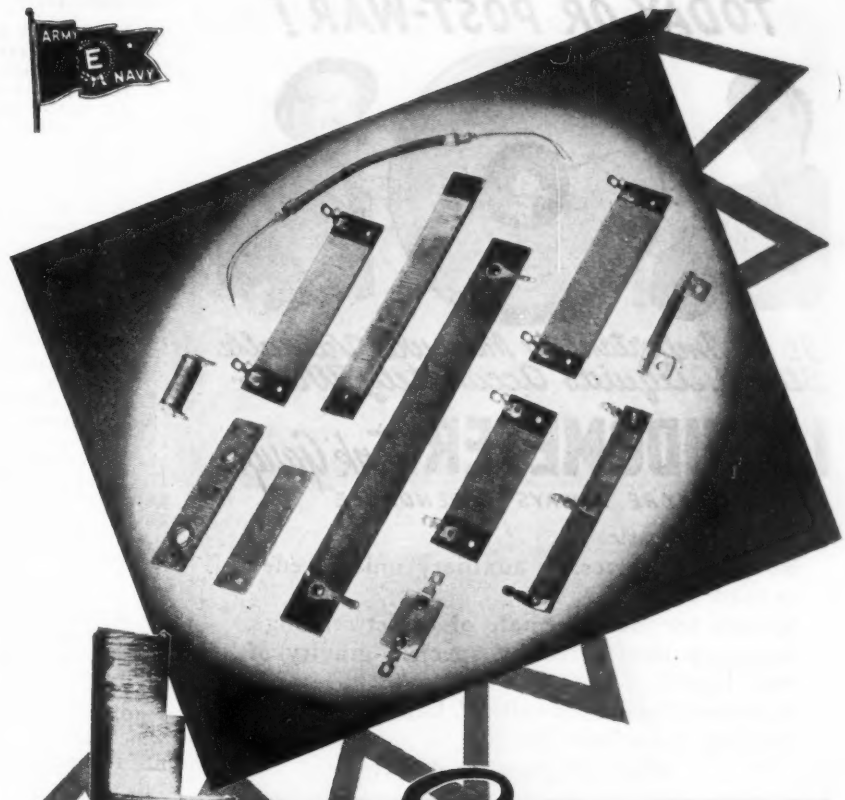


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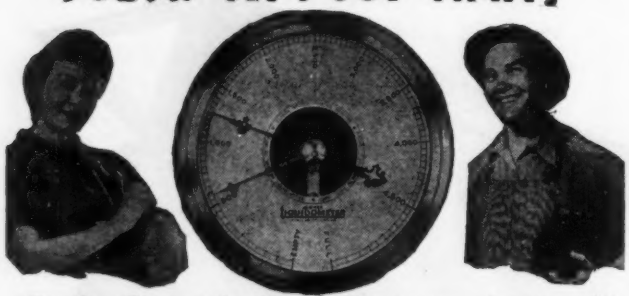

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   A. Half-wave
   B. Full-wave
2. High-power high-vacuum rectifiers
   All half-wave
3. Gas rectifiers
   A. Half-wave
   B. Full-wave
4. General-purpose triodes (low power)
   May be used as detector, oscillator, voltage and low-power amplifiers
5. General-purpose triodes (intermediate power)
6. Class B triodes
   Special Class B power amplifiers—triodes and duotriodes operated with no bias on control grid
7. Class B and Class C Power-Amplifier Triodes (intermediate power)
   Used particularly for Class B and C amplifiers and oscillators
8. Water-cooled Triodes
9. Internally screened voltage-amplifier tetrodes and pentodes
10. Unscreened Power-amplifier tetrodes and pentodes
11. Internally screened power-amplifier tetrodes and pentodes
12. Duodiode-triodes and duodiodes
13. Duodiode-pentodes and triode pentodes
14. Special five-grid oscillator-modulators and frequency converters
15. Special ultra-high-frequency oscillators
    A. Split-anode magnetrons
    B. Electrnic oscillators
16. Electrometers
17. Current regulators
18. Voltage regulators and surge protectors
19. Ionization gages

rectifiers. Group II lists high-power high-vacuum rectifiers which are all of the half-wave type. Group III lists gas-filled rectifiers, also subdivided into half-wave and full-wave tubes, and so on. A complete list of these groups is shown in the accompanying tabulation. There is of course nothing standard about this classification and various other groupings are possible, but it does show the wide variety of functions to which electron tubes can be adapted.

*(To be continued)*

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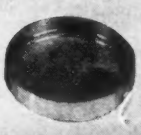

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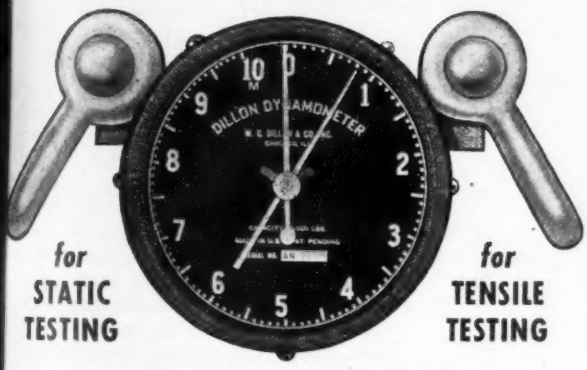


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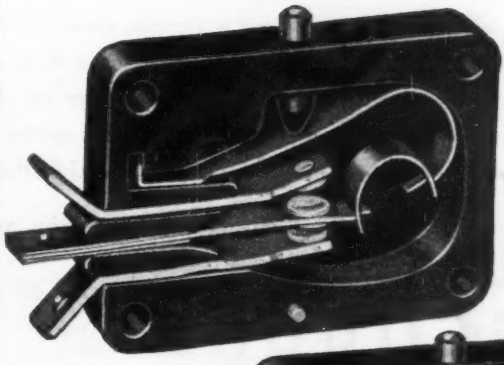

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## Temperature Instruments

*(Concluded from page 472)*

The spectral response of a typical photocell is shown in Fig. 19, together with the spectral radiation from a blackbody at various temperatures. The relative response of the cell to radiation at various temperatures is indicated by the parts of the area under the sensitivity curve common to the areas under the radiation curves. Thus it is apparent that the sensitivity varies very rapidly with temperature and is almost negligible at 1800° F. and lower. The sensitivity at 1800° is so low that relatively intense radiation is required to provide a readily measurable current. Since most of the radiation at ordinary high temperatures lies in the infrared, it is necessary to be careful not to overheat the cell. This somewhat serious limitation of the usefulness of this cell is offset considerably by the fact that as a radiation pyrometer it is much less affected by the presence of carbon dioxide and water vapor in a furnace, and hence its probable performance in a particular case can be more reliably estimated by observation, than can that of a thermopile (thermocouple receiver). In other words, what one sees by looking into a furnace is a rather truthful criterion of what a "Photronic" cell sees, while on the other hand the furnace atmosphere may appear very dense to the thermopile if it consists largely of carbon dioxide and water vapor.

The rapidity of response of the "Photronic" cell has been put to good use in the measurement of temperatures of hot strip in the strip mill, where these temperatures are high enough. A few hundred feet of strip at a uniform temperature can pass in view of a thermopile before its response

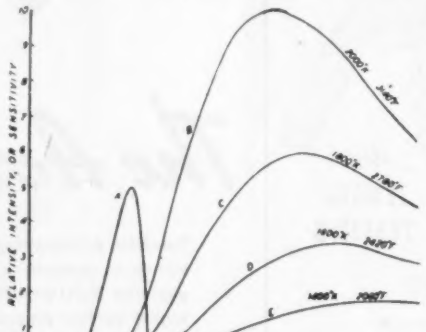



*Fig. 19* A — PHOTOELECTRIC CELL SENSITIVITY
B,C,D,E — INTENSITY OF RADIATION FROM BLACK BODY

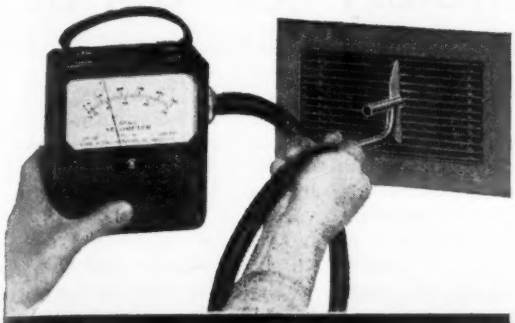
has nearly reached a maximum. The "Photronic" cell is much faster than any known indicating or recording instrument. A slight hysteresis is observable in this cell, inconsequential in pyrometry although of some significance in precise photometry.

The characteristics of the "Photronic" cell have been also used to advantage in the measurement of open-hearth bath temperatures by engineers of the U. S. Steel Corporation, as described by Sordahl and Sosman in their A. I. P. Temperature Symposium paper, "Measuring Open-hearth Bath Temperatures," which was printed in *Instruments*, May 1940, pages 127-130.

### SUMMARY

Perhaps it would be out of place for us to compare the performance characteristics of the various instruments described, and we can leave this problem to the claims of the makers. Development has been fairly rapid during the last few years, and we can expect that it will continue to be so for some time to come. We can look forward to an instrument so accurate, fast, simple and reliable, that maintenance will some day be a negligible factor.

The need for rapid recording of temperature is not new, but it has been more pressing lately, in the strip mill and in the catalytic oil refinery, to mention two cases in industrial applications, and also in research laboratories, either for studying rapidly changing temperatures, as in quenching steel, or for measuring a large number of temperatures in reasonably short cycles. Various high-speed methods were predicted by M. F. Behar in the Oct. 1940 *Instruments*, page 294, par. 7-8. So far as we are aware, the fastest known method is in the use of a movie camera set up before an array of indicators, a method employed as long ago as 1917 or 1918 in testing airplanes. An electronic recorder to equal this arrangement for speed might be expected within a few years.



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# An "Anticipatory" Control Scheme

By C. E. DIEHL, Spanish Fork, Utah

WHERE accurate control of chemical reactions is necessary it is desirable to determine quality of output before the reaction is complete. In other words we must anticipate the character of the product before it is produced. The only method that can give such a result is analysis of input chemicals and accurate proportioning of these chemicals.

As the most common variation in quality of chemicals in solution was found to be a change of concentration, and as concentration is measurable in inorganic solutions by conductivity measurements, this method has been adopted to control quantity of input as quality changes.

The concentration control is superimposed upon a pH controller which controls ratio of mix to produce desired output. Since the pH controller measures output and changes input, there is a considerable delay before the effect of an input change can be measured. In other words, by reason of the process dead-time, the pH controller forms the mix of the unformed chemical from an analysis of a previously-completed product. If there is much variation of quality of input chemicals, the output changes in quality. At times, the variation is throughout an entirely undesirable range. The addition of the anticipatory type of control smooths out these variations.

Fig. 1 is a schematic flow sheet. Fig. 2 is the basic circuit of the conductivity cells. The combined control relay operated by both the conductivity cells and the pH cell is shown in Fig. 3.

In Fig. 1 the motors *A* and *B* are valve-operating motors. The motor-operated valves control a certain percentage of the flow of the input chemicals which is under control of an operator by the adjustment of hand-operated valves in parallel flow to these. These motors are connected to the same reversing controller and so arranged that when one is opening the valve (i.e. *A*) the other is closing the valve (i.e. *B*). Cells *A* and *B* are conductivity cells through which a small portion of the input chemicals are by-passed. These cells indicate the concentration of the solution that is passing through them. These cells are so connected that decrease in concentration of either chemical *A* or *B* will change position of valves to increase flow of the weakened chemical and decrease the flow of the stronger. This anticipates the changed composition of the mix "*AB*."

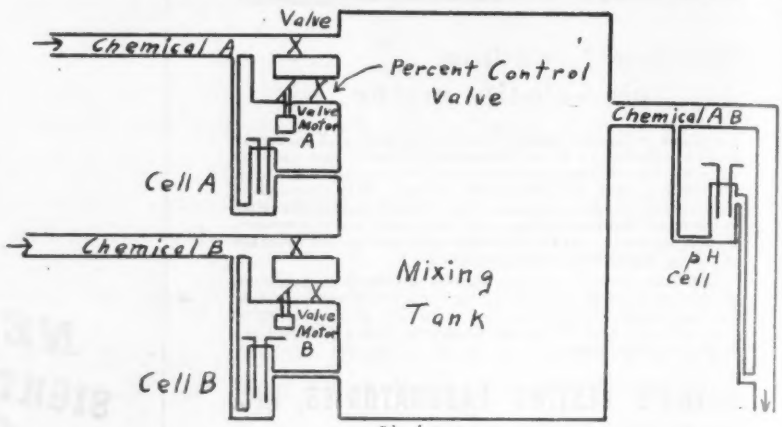

Fig. 1

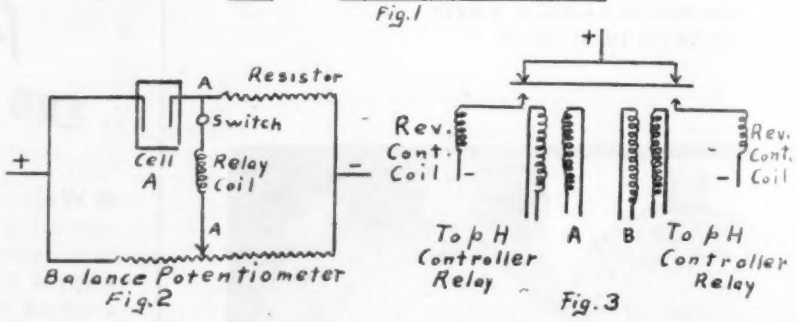

Fig. 2 Fig. 3

The pH cell is likewise interconnected to valve motors *A* and *B* and thus controls the proportions of the mix of chemicals *A* and *B* to produce desired value of product delivered.

In practice, flow is started with cells *A* and *B* inoperative. Upon delivery of desired product, the cells are cut in, so balanced that no movement of the valves takes place due to the influence of these cells. The conductivity of the solutions changing will cause a movement of the valves to correct the flow to compensate for this change. The pH cell acts as Master Controller for quality of the finished product.


REFERENCE

C. E. Diehl. "Automatic pH Control Converts a Batch Process to Continuous flow." *Instruments*, January 1941, page 15.

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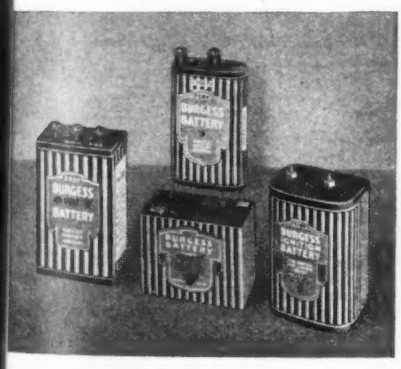

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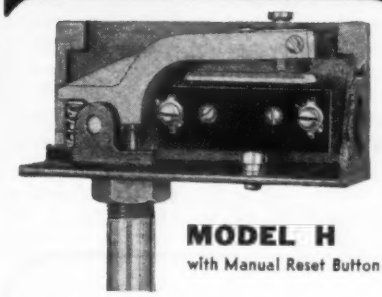

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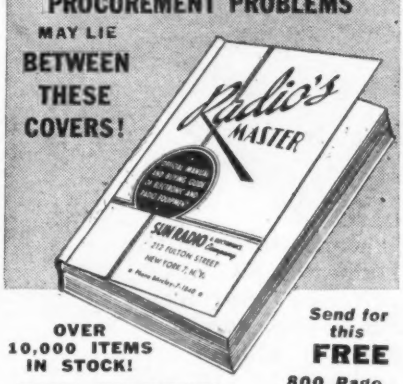


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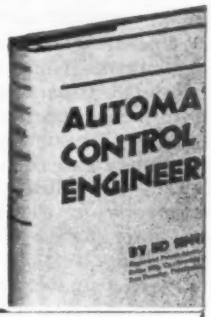


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ED SINCLAIR SMITH

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## Practical Color Photoptometry

*(Concluded from page 474)*

health of the subject.[13] Febrile states, mild infections (head cold, etc.) and hypoproteinemic states due to malnutrition, as a rule decrease the duration of the positive after-images.

Operating the various knobs of the instrument from remote controls enables one to *measure the intensity and color characteristics* of the various phases of recurring vision. Such measurements call for a little patience and entail the difficulty that in some cases the color of the after-image is more saturated than even spectral colors (McDougall[14]). Such measurements appear valuable in the interpretation of the various electrical current actions taking place during the manifestation of recurrent vision, part of them being now known to originate along the optical pathway as well as in the brain (Barthley[15]).

Reliable figures in experiments of the type related above can be obtained only if the biological material (the eyes) is considered in a known, stabilized, physiological state. Such reference state can be readily ascertained by means of the instrument itself, since it permits the determination of the threshold of sensibility *under definite conditions*. Indeed, it has now been demonstrated by Hecht[16] that at the threshold where only a few quanta of energy are involved (5 to 14 possibly) the stability of the photochemical process *in the reference physiological state* is such that possible quantic fluctuations of the stimulating source (following a Poisson distribution curve) must be accounted for. Consequently the light source was energized through a suitable transformer, a voltage stabilizer and a potentiometric circuit.

The instrument was primarily intended as a color mixer. By adjunction of a photometric prism and a standard yellow-colored comparison area, it was found useful for the detection of various mild dyschromatopsis. Such studies were performed upon subjects to be submitted to various psychophysiological experiments[17,18,19,20] of a statistical nature connected with the study of glare, experiments where the homogeneity of the biological material must be ascertained. The insertion of a semi-transparent optotest of convenient size in the above arrangement, between the observation area and the photometric prism, makes the instrument suitable for chromoptometric determinations. Subjects with refractometric abnormalities were found to require color mixtures different from those composed by normal subjects, for obtaining equal haziness of the two halves of the optotest as seen through the apparatus. The method is extremely sensitive.

Obviously, the same principle could be applied to the construction of a sensitive colorimeter eliminating all the disadvantages of heterochromic matches, and data will be reported elsewhere showing that such an instrument affords an exceptionally high degree of accuracy and reliability when used for colorimetry of solutions.

(13) Jean Escher-Desrivières and Raymond Jonnard. Etudes sur la Durée des Images Dites Accidentelles Consécutives à Une Illumination de l'Oeil. *Comptes Rendus Hebdomadaires des Séances et Mémoires de la Société de Biologie*, Vol. 120, Nov. 16, 1935, pages 681-684.

(14) W. McDougall. Some new Observations in Support of Thomas Young's Theory of Light-and-colour Vision. Part II: Colour Vision. *Mind*. N. S. Vol. 10, April 1901, pages 210-245.

(15) Howard S. Bartley. Visual Sensation and its Dependence on the Neurophysiology of the Optic Pathway. *Biological Symposia*, Vol. 7, 1942, pages 87-106.

(16) Selig Hecht. Energy Relations in Vision. *Biological Symposia*, Vol. 7, 1942, pages 1-21.

(17) Robert Faillie and Raymond Jonnard. Nouveau Dispositif pour la Mesure des Temps de Réaction Psychomotrices. *Travail Humain*, Vol. 1, 1933, pages 1-7.

(18) Raymond Jonnard and Luce Maire. Influence de Quelques Substances Usuelles sur les Temps de Réaction Visuels à Signal Auditifs. *Paris Médical*, Vol. 2, Oct. 1933, pages 273-278.

(19) Raymond Jonnard, Jean Escher-Desrivières, Robert Faillie and Henri Vial de Sachy. Réactions Psychomotrices Visuelles en Relation avec l'Eblouissement par Projecteur d'Automobile. *Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences*, Vol. 197, Oct. 2, 1933, pages 699-701.

(20) Raymond Jonnard, Jean Escher-Desrivières and Robert Faillie. Réactions Psychomotrices Visuelles Consécutives à une Illumination Intense de l'Oeil. *Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences*, Vol. 198, April 4, 1934, pages 1325-1328.

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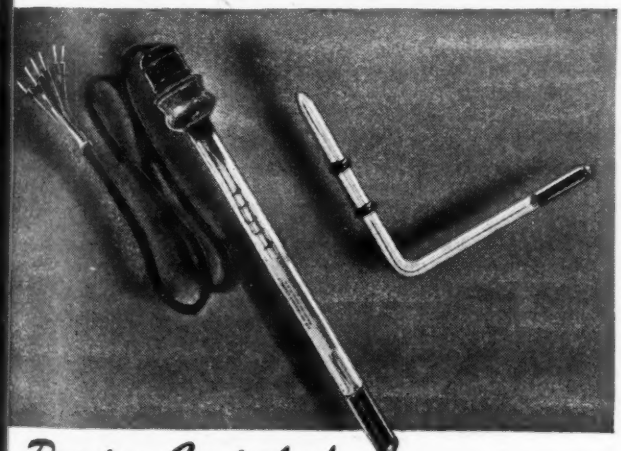

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## INSTRUMENT SOCIETIES CALENDAR

| City | Society and Secretary | | Date | Place | Subject | Speaker |
|---|---|---|---|---|---|---|
| Atlanta | Georgia Society for Measurement & Control | Roger W. Allen, 376 Nelson St., S.W., Atlanta | | | | |
| Baltimore | Baltimore Industrial Instrumentation Society | C. B. Willnecker, 6732 Danville Ave., Dundalk, Md. | | | | |
| Chicago | Chicago Society for Measurement & Control | A. J. Butler, 2626 W. 31st Blvd., Chicago | | | | |
| Cleveland | Cleveland Instrumentation Society | W. A. Stubblefield, 2085 W. 104th St., Cleveland 2 | | | | |
| Fort Worth | Fort Worth Electronics Club | | Aug. 17 | To be announced | Electronic Gaging | To be announced |
| Gulf Coast | Gulf Coast Instrument Maintenance Men's Ass'n | T. H. Pierson, 3030 Roberts St., Beaumont, Tex. | | | | |
| Hartford | Hartford Society for Measurement & Control | S. J. Zelle, Whitney Chain & Mfg. Co., Box 1410, Hartford, Conn. | | | | |
| Kansas City | KC Industrial Instrumentation Society | Gordon H. Burke, 1527 Broadway, Kansas City, Mo. | Aug. 29(B) | Bluebird Cafeteria | Pressure Control | Paul Elfers, Fisher Governor Co. |
| Newark | New Jersey Society for Measurement & Control | Robert H. Gray, 1 Whippoorwill Way, Mountainside, N. J. | | | | |
| New York | New York Society for Measurement & Control | H. R. Kalbfleisch, 144-35 No. Blvd., Flushing, N. Y. | | | | |
| N. Indiana | Northern Indiana Soc. Measurement & Control | R. W. Schreiner, 4 Waltham St. Calumet City, Illinois | | | | |
| Philadelphia | Philadelphia Society for Instrumentation | J. E. Gambrill, 1317 Spruce St. | Sept. 20(B) | Engineers Club | Inter-connected Instruments | J. A. Pellettere, Gulf Oil Corp. |
| | | | Oct. 18(B) | Engineers Club | Combustion Control | M. J. Boho, Hagan Corp. |
| Pittsburgh | American Society for Measurement & Control | L. M. Susany, c/o Carnegie Institute, 4400 Forbes St., Pgh. | Sept. 25(B) | Roosevelt Hotel | Instruments and Synthetic Rubber | J. G. Kirkpatrick, Koppers United Co. |
| | | | Oct. 23(B) | Roosevelt Hotel | Flow Measurement Eng'g | L. K. Spink, Foxboro Co. |
| St. Louis | St. Louis Society for Instrumentation | Gus Holubeck, Union Electric Co., Venice, Ill. | | | | |
| Toronto | Canadian Society for Measurement & Control | T. C. Agnew, Minneapolis-Honeywell Reg. Co., Toronto | | | | |
| Washington | Instruments Society of Washington | W. A. Wildhack, 328 N. Oxford St., Arlington, Va. | | | | |
| Wyandotte | Instrument Society of Wayne County | John MacPherson, RFD No. 1, Wyandotte, Mich. | Sept. 25(B) | Presbyterian Church Hall | Process Instruments and Control | Ralph Cowan, Bailey Meter Co. |

(A)Meeting at 7:30, no dinner. (B)Dinner at 6:30, meeting at 8. (C)Dinner at 7, meeting at 8. (D)Meeting at 8, no dinner.

### CLEVELAND

We haven't had a meeting since May 23rd, but hope to have a meeting of the officers and program committee in the near future.

We have had two speakers so far in our short life. The first was Mr. Lyle Cahill of the Jack & Heintz Co. of March 29, who explained the operation of automatic pilots, using both slides and exhibits of captured enemy equipment. His talk was over the heads of most of us, but was nevertheless thoroughly interesting.

The second speaker, on May 23, was A. Hejduk of the Meriam Instrument Co., whose subject was "Manometer Applications in Industry." He described several unique uses of manometers as applied to war production, and also explained some of the more common applications which many of us thought we understood, but discovered that we didn't.

Results of the election held at our May 23rd meeting: Chairman, R. Meulenberg, Du Pont Co.; Vice-chairman, W. Buhl, Jack & Heintz Co.; Sec'y, W. A. Stubblefield, Republic Steel Co.; Treas., W. Eberle, Hickok Electrical Instrument Co.; Chairman of Program Committee, Wm. Sachse, Standard Oil Co. —RICHARD G. MEULENBERG

### FORT WORTH ELECTRONICS CLUB
FORT WORTH, TEXAS

To the Editor of *Instruments*: I submit the following as a news item for your magazine. The Fort Worth Electronics Club was organized June 22nd, 1944, composed of nineteen charter members employed in various industries in Fort Worth, all interested generally and in some specific way in industrial application of electronics.

The object of the Club as set forth in its constitution is to form and maintain a group of individuals, interested in the subject of electronics, united in good fellowship, for the purpose of improving each member's understanding and knowledge of the subject, through study, mutual instruction and discussion.

Regular meetings are held once each month at which time one or more members present an instructive program, on some specific phase or application of electronics, after which the meeting is thrown open for discussion.

One regular meeting has been held. The subject was "Electronic Control of Resistance Welding." The next regular meeting will be held August 17th at which time the program subject will be "Electronic Gaging."

Officers: *Pres.*, Wendel C. Fowler; *Vice Pres.*, Roy P. Bates; *Sec.-Treas.*, R. A. Ely.

*July 26, 1944* —RALPH A. ELY

### KANSAS CITY

Although some of our members were out of town, others on vacations, and the weather was hot (which is unusual for Kansas City) a representative number of our membership attended the July 25 regular meeting at the Bluebird Cafeteria.

William G. Eargle, Instrument foreman, Phillips Petroleum Co., Kansas City, Kansas, and our Vice-president, presented an introductory basic lecture on liquid level instruments.

Our quiz kids, Lester Johnson, Sinclair Refining Co., K. C. Kansas; Roy Carns, Sinclair Refining Co., K. C. Kansas; William G. Eargle, Phillips Petroleum Co., K. C. Kansas; and J. O. Smith, Phillips Petroleum Co., K. C. Kansas; entertained the members with their enlightening answers to various questions on liquid level instruments.

P. E. Bjork, Assistant chief engineer, Lindberg Engineering Co., Chicago, presented his illustrated lecture on "Furnaces and their Associated Controls." What Mr. Bjork, better known as "Whitie" did not know about furnaces and their controls was not asked. Whitie really put on a splendid talk, and the members went away knowing much more about furnaces and their controls than they had ever known before. An evening well spent. —W. A. REICHOW

### NEWARK

The June 6 meeting of the Society for Measurement and Control (N. J.) was attended by nearly 100, including a large delegation from the New York Society. Mr. C. O. Fairchild, Director of Research, C. J. Tagliabue Mfg. Co., emphasized the salient points of a new paper he had just completed, preprints having been sent previously to members. His paper describes the fundamentals of all commercially-available electronic pyrometers. [See p. 368 of this issue. — ED. *Instruments.*] Mr. Fairchild brought out one point not covered in his paper when he discussed the use of galvanometers in pyrometry. He pointed out that galvanometers have been so highly developed and are capable of such tremendous multiplication of input (when used with phototubes) that they would not be entirely replaced by electronic non-balance detectors. As an example of the multiplication he mentioned that a mirror galvanometer and sensitive phototube would amplify the input one to two million times, while most electronic non-balanced detectors only multiply it several hundred thousand times. In connection he demonstrated a new galvanometer exhibiting unusual vibration- and shock-resistance combined with good zero stability.

Long after the meeting formally adjourned, Mr. Fairchild was still surrounded by questioners. —R. H. GRAY

### NEW YORK and NEW JERSEY

The New York and New Jersey societies have completed arrangements for joint associate memberships. By the payment of a nominal fee to cover postage, a member of one of the societies can receive the meeting announcements of the other society. While Instruments list the meetings, subject, and speakers, the announcements are more detailed and are direct reminders. The large number of New York members attending the June meeting of the New Jersey group attests to the desirability of this arrange-

ment. An Annual Joint Meeting is planned, and this year New York will be the host on November 14 when Dr. R. B. Sosman of U. S. Steel Research Laboratory is expected to speak. The meeting will be held at the Building Trades Employers' Association, 2 Park Ave., New York, with dinner at seven and the meeting at eight o'clock. All instrument engineers are invited. —R.H.G.

### NEW YORK

At our last Spring meeting, June 27th, M. H. White of Atlantic Refining Company spoke on "Petroleum Refinery Instrument Maintenance." This was the most unusual meeting of the year as the speaker talked about the problems of instrument maintenance from the user's point of view. First the requirements of such a job and the organization necessary to handle such work were discussed in detail. Then followed a description of the training program for instrument technicians on this type of work. In conclusion the systems used for making repairs and routine tests were related along with their method of recording the history of each instrument. During the discussion period Mr. White answered many questions which showed the interest of both the manufacturer and the users in the maintenance of industrial instruments. It was generally agreed that this was the most successful meeting of the year. —H. R. KALBFLEISCH

### NORTHERN INDIANA SOCIETY FOR MEASUREMENT AND CONTROL

EDUCATION—FRATERNITY—DEMOCRACY

At the July meeting of the Executive Committee, events to take place next year and committeemen were selected. PROGRAM COMMITTEE: *Chairman*, David Bohheur, Tubular Alloy Steel; Orville Danford, Tubular Alloy Steel; Edward White, Socony Vacuum Oil Co.; Jon Beam, Cities Service Oil Co.; Ray W. Schreiner, Continental Foundry & Machine Co. MEMBERSHIP COMMITTEE: *Chairman*, Robert L. Meinzer, Cities Service Oil Co.; Lee Dunn, Tubular Alloy Steel; Kenneth M. Frame, Standard Oil Co.; Joseph Rudman and Joseph Sgambelluri, Gary Sheet Mill. EDUCATIONAL COMMITTEE: *Chairman*, Ernest Opocensky, Socony Vacuum Oil Co.; Paul Montgomery, Carnegie-Illinois Steel Co.; Henry F. Wagner, Gary Sheet Mill; Charles Haynes, Red River Refinery Co.; Alexander Churchman, Socony Vacuum Oil Co. The committees will meet during the next month.

—K. M. FRAME

### WYANDOTTE

The Instrument Society of Wayne County reports. We have about sixty members, a constitution and by-laws. Men occupied in use, maintenance, installation and repair of instruments are eligible as active members and men occupied as salesmen, manufacturers, designers, etc. are eligible as associate members. We have had several meetings, each consisting of a banquet followed by a talk by an instrument sales representative. Our July meeting was a basket picnic with coffee, ice cream, and soft drinks furnished by the Society. There was a big turnout, a lively ball game, all our families got acquainted, and the Society got some publicity. —JOHN MACPHERSON

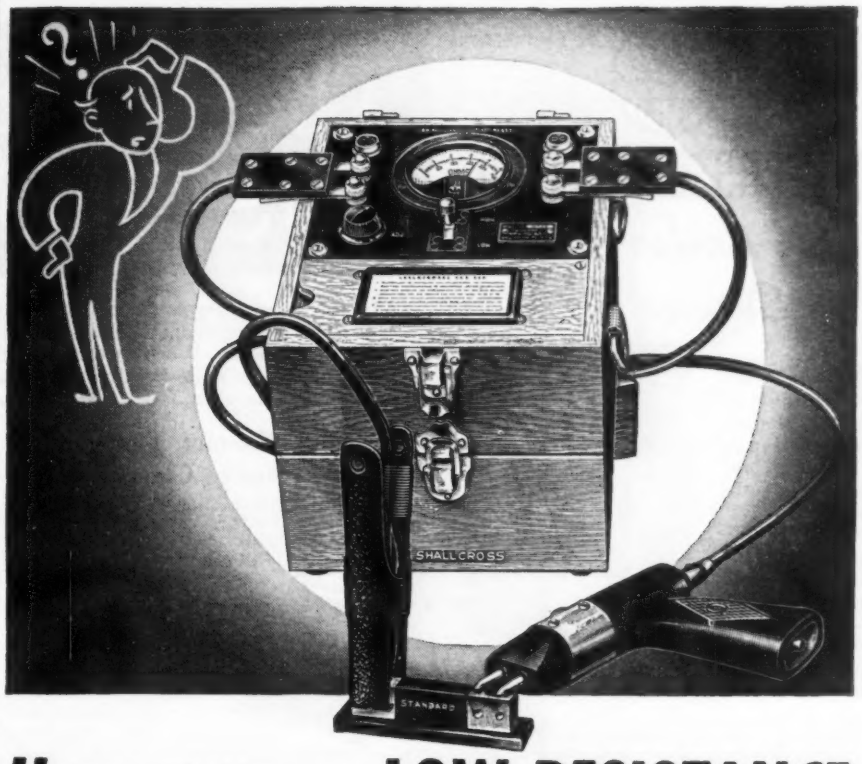
### NATIONAL TIME AND MOTION STUDY CLINIC

Sponsored by the Industrial Management Society, the Eighth Annual Time & Motion Study Clinic for engineers, executives and supervisors has a program of interest to everyone in the industrial field, will be held November 2 and 3, 1944, at the Medinah Club, Chicago, Illinois. Outstanding speakers such as Allan H. Mogenson, Lillian S. Gilbreth and Ralph M. Barnes are on the program. The Clinic theme will be "More Production with Less Effort."

### S.E.S.A.

The Fall Meeting of the SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS will be held at The Carter Hotel, Cleveland, Ohio, October 17, 18, 19, 20, 1944, during the same week as the National Metal Congress.

Inquiries should be addressed to Society for Experimental Stress Analysis, P. O. Box 168, Cambridge 39, Massachusetts.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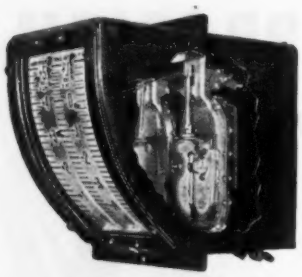

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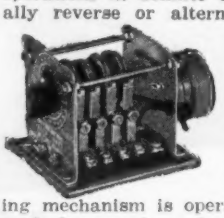
# The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions. When writing to manufacturers directly, please mention this department. Or write to Information Section, Instruments Publishing Company.

## Multi-Contact Timer for Remote Control

New Multi-Contact Timer for remote control is used to control a series of machine operations in definite order; to automatically reverse or alternate in operation a group of motors, machines or devices; to operate in a predetermined sequence a series of signals, valves or solenoids; and for sequence operations. Its solenoid starting mechanism is operated from a remote control momentary start button, so that the timer will go through its complete cycle or any part of its cycle of operation and stop. Reclosing momentary start button will either continue or repeat cycle (as the case may be). Timer can be arranged so that in event of a power interruption it is necessary to again press remote control start button to continue the cycle, or, after power is restored, to automatically continue cycle of operation.—*The R. W. Cramer Co., Inc., Centerbrook, Conn.*



## Rheostats with Percent Scales and Clamps

New line of "Rex" protected rheostats features improvements, among which is a scale dividing the length of the winding in 100 equal parts. Fig. 1 shows in actual size

Fig. 1

a portion of the scale used for "Type 6." Ohmic value of resistance in circuit is the same as the value stamped on nameplate, multiplied by the number under the mark on the slider, divided by 100. This value will be of help to the operator in that he can easily determine amperage in circuit, when voltage and load resistance are constant, without the use of an ammeter. Scale also enables operator to mark special points so that the rheostat can be reset easily. Listed rheostats of the six different sizes are furnished with these scales at no additional cost. Fig. 2 shows the rheostat with new slider clamp, which enables the user to fix slider in any position so that slider cannot be moved accidentally or through other forces such as vibration. Unprotected "Rex" rheostats can also be furnished with this slider clamp.—*Rex Rheostat Co., 3 Fox-hurst Road, Baldwin, L. I., N. Y.*

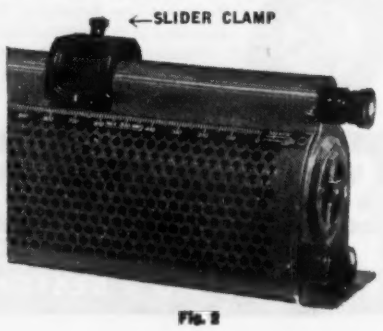
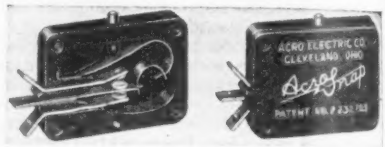



Fig. 2

## Extremely Small Snap Switch

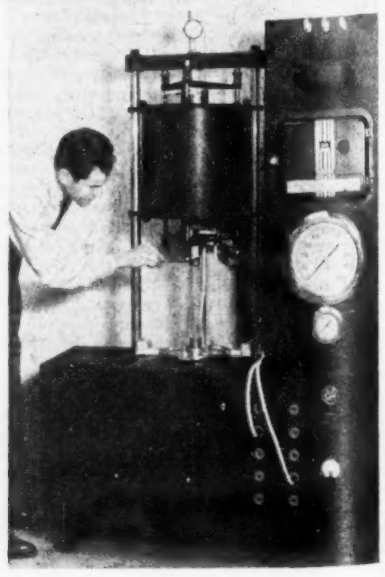
New "Miniac" snap switch is said to be "the smallest fully enclosed snap-action switch ever built." It is $1\frac{7}{64}$" thick, $1\frac{3}{16}$" high and $1\frac{9}{16}$" long. It utilizes maker's



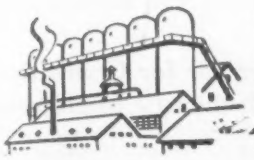

rolling-spring principle which was fully described in *Instruments*, August 1941, page 222, but with a new design and smaller size. Fully enclosed in a Bakelite case with four $\frac{3}{32}$" mounting holes. Actuation is with a stainless steel pin plunger. All parts are non-corrosive and all contacts are of fine silver. Main blade, contact blade, and rolling spring of beryllium copper. Rated at 15 amps., 115 volts a.c. Furnished in single-pole, normally open and normally closed, double-throw. Designed to permit leaf type or overtravel plunger type actuators to be attached to case.—*Acro Electric Co., 1324 Superior Ave., Cleveland 14, Ohio.*

## Dilatometer

New dilatometer, for high-temperature testing of foundry molding and ceramic materials, has a furnace that will operate between 500 and 3000°F. Test specimen size $1\frac{1}{8}$" diam. and 2" long. To determine hot strength of specimen, specimen is loaded in furnace by means of a motor-



# MECHANICAL GUARDIANS FOR CHEMICAL PIPE-LINES



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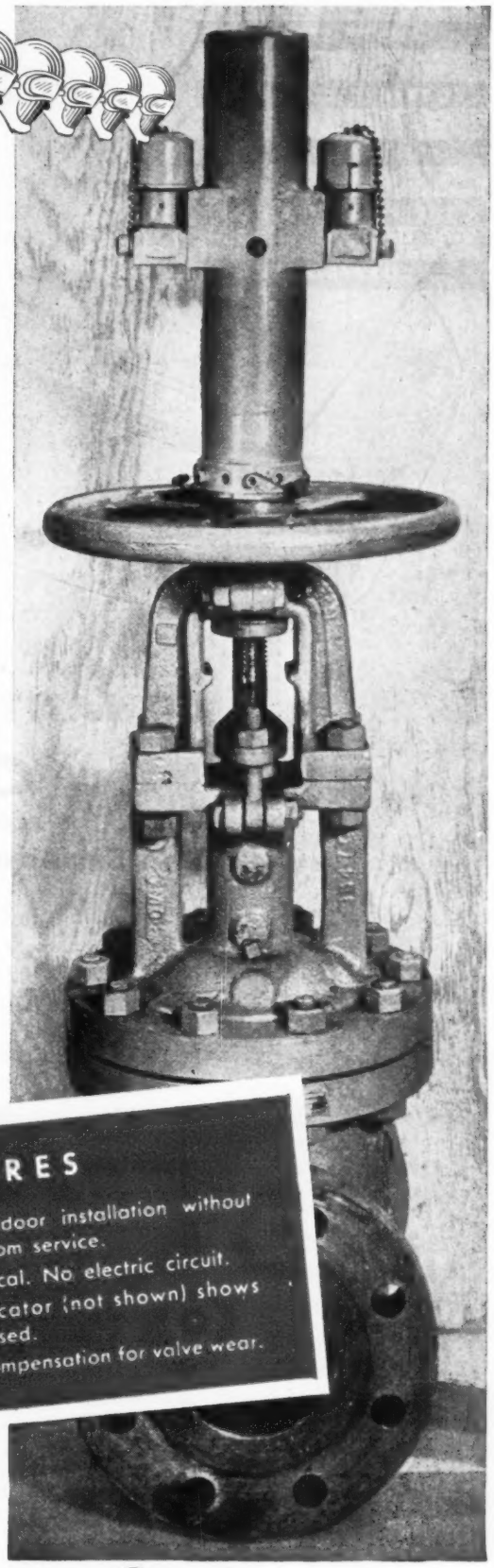

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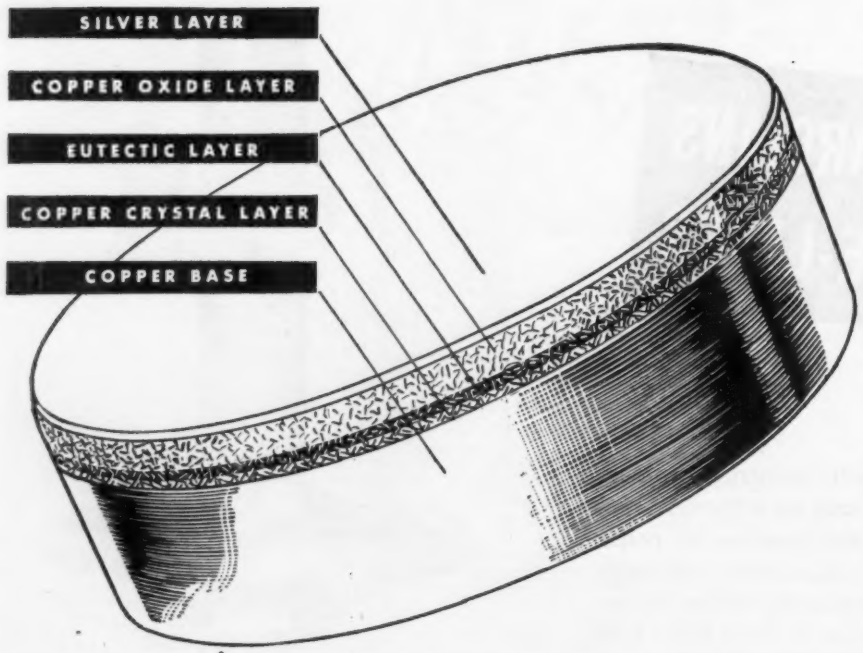


# CONANT RECTIFIERS *Still*

## The Standard of Perfection

In the manufacture of Conant rectifiers, the layer of copper oxide is formed in the usual manner but it is then caused to alloy with the underlying copper to form a copper-copper oxide eutectic. Then by careful control of timing and temperatures, the eutectic alloy is caused to crystallize in a form resulting in a very stable asymmetric junction especially suited for instrument applications. The molecular structure of the junction so formed required the development of new and unusual processing methods.

Every step in the Conant process has been correctly developed. From the precision lapping of the discs, through the application of the contacting layers and chemical treatments, to the final assembly, each careful operation assures a rectifier assembly that will give the utmost satisfaction in instrument service.

Yes, Conant rectifiers are different, because of the extra care and the plus precision that go into their manufacture. Their enviable record of service is the proof.

*Instrument Rectifiers*

CONANT ELECTRICAL LABORATORIES

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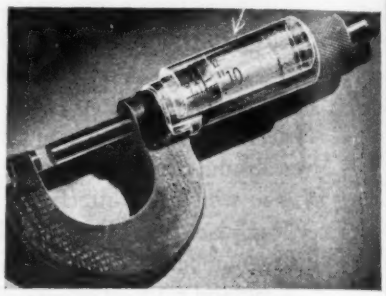
1526 Ivy St., Denver, Colo.
4214 Country Club Dr., Long Beach 7, Cal.
4205 N.E. 22nd Ave., Portland 11, Ore.
Caixa Postal 930, Sao Paulo, Brazil
50 Yarmouth Rd., Toronto, Canada


driven hydraulic-operated plunger which may be used to load specimen in compression. Compression strength is recorded on a large test gage. Expansion or contraction of specimen is readily obtained either for thermal shock or for gradual temperature rise. Both free and confined expansion or contraction tests can be made. Dilatometer unit also lends itself to spalling tests for either shock or gradual temperature immersion. Accessories are available to measure hot permeability of materials at high temperatures. Gas pressure created by materials at high temperature is also measured with this unit. For studying troublesome foundry problems, test methods and accessories are available for determining metal penetration, veining and grooving. With this same equipment, one may measure the facing or protective value of various foundry or glazing materials. All of controls are mounted on a panel, making entire unit self-contained and easy to operate.—*Harry W. Dietert Co., 9330 Roselawn Ave., Detroit, Mich.*

## Magnifier for Graduations of Machinists' Micrometers

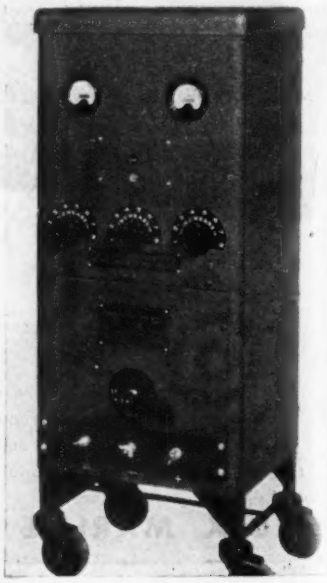
New "Magna-Eye" is a special magnifier, of methyl methacrylate, fitting closely over scale of hand micrometers such as are used



by toolmakers, inspectors, etc. Combination of magnification and light-gathering makes graduations readable under poor illumination, speeding up production. Announcement states also that "Magna-Eye protects the micrometer from dust and dirt, making frequent cleanings unnecessary." — *Stebar Mechanical & Electrical Research Lab., 711 W. Lake St., Minneapolis 8, Minn.*

## Portable D-c. Power Supply

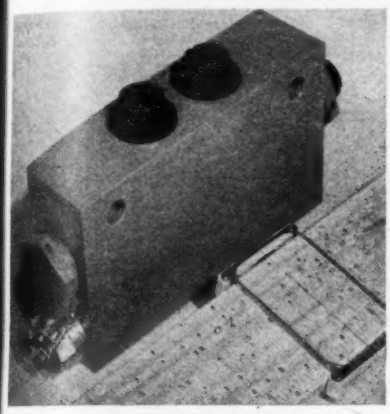
New portable d-c. power supply is designed for use on assembly lines, in laboratories and maintenance departments, for testing and operating all electrical and electronic equipment in aircraft and other units employing 12- or 24-volt systems. It



can also be used to taper charge batteries or battery carts of similar voltages. Unit is designed to operate from 3-phase a-c. lines of 208 and 230 volts. Three models are offered: "No. VA1500," with d-c. output of 10 to 16 volts at 100 amps. or 20 to 32 volts at 50 amps.; "No. VA3000," with d-c. output of 10 to 16 volts at 200 amps. or 20 to 32 volts at 100 amps.; "No. VA4500," with d-c. output of 10 to 16 volts at 300 amps. or 20 to 32 volts at 150 amps. Models with similar d-c. output but for operation on 460 volts a.c. are also available. Rectification is provided by maker's magnesium-copper sulphide dry disk rectifiers.—*P. R. Mallory & Co., Inc., Indianapolis, Ind.*

## Hydraulic Lock Valves for Leakage Safeguard

Three new small light-weight hydraulic lock valves are designed to protect vital controls against operation failures due to leakage. They lock hydraulic fluid in cylin-



ders or hydraulic motors until the directional control valve is operated, thus maintaining pressure in mechanism. They hydraulically lock the cylinder and are opened by pressure released by the selector valve. Critical operating parts are of corrosion-resistant steel. Bodies are of dural bar stock free from porosity. A thermal relief valve is incorporated in each lock valve cylinder port to be bleed off excess pressure at 1200 to 2000 lbs./in.$^2$ depending on requirements. Operation range is from—65°F. to 160°F. "Type D12940" (illustrated) weighs 1.18 lbs., measures 4" × 2 1/16" × 1 1/4". Valves may be obtained for various tubing size installations.—*Adel Precision Products Corp., Burbank, Calif.*

## Pressure Switch

New pressure switch is designed for solenoid valves, for automatic control of operating cycles on hydraulic machines, for controlling of pumps or compressors, for operating and safety controls in chemical

Small . . . but MIGHTY!

. . . this 3-POUND MIDGET "MEGGER"* TESTER generates *500 VOLTS* and reads up to 50 Megohms

Basically designed for maintenance men, this mighty midget is used by many engineers for testing insulation resistance of practically all types of electrical equipment. Because it is small enough to fit an overcoat pocket or tool kit, and because of its instrument accuracy and machine ruggedness it has proved itself indispensable for maintenance and trouble shooting, even where higher range "Megger" sets are available. The hand cranked generator delivers 500 volts and since no batteries or external power supply are required, it is always ready for use . . . anywhere.

If you are not already familiar with this smallest and in many ways the most remarkable member of the "Megger" family, write for Bulletin 1545-I and Catalog 1685-I.

*Ask also for Bulletin 1735-I describing the new U. S.-made "Megger" Testers.*

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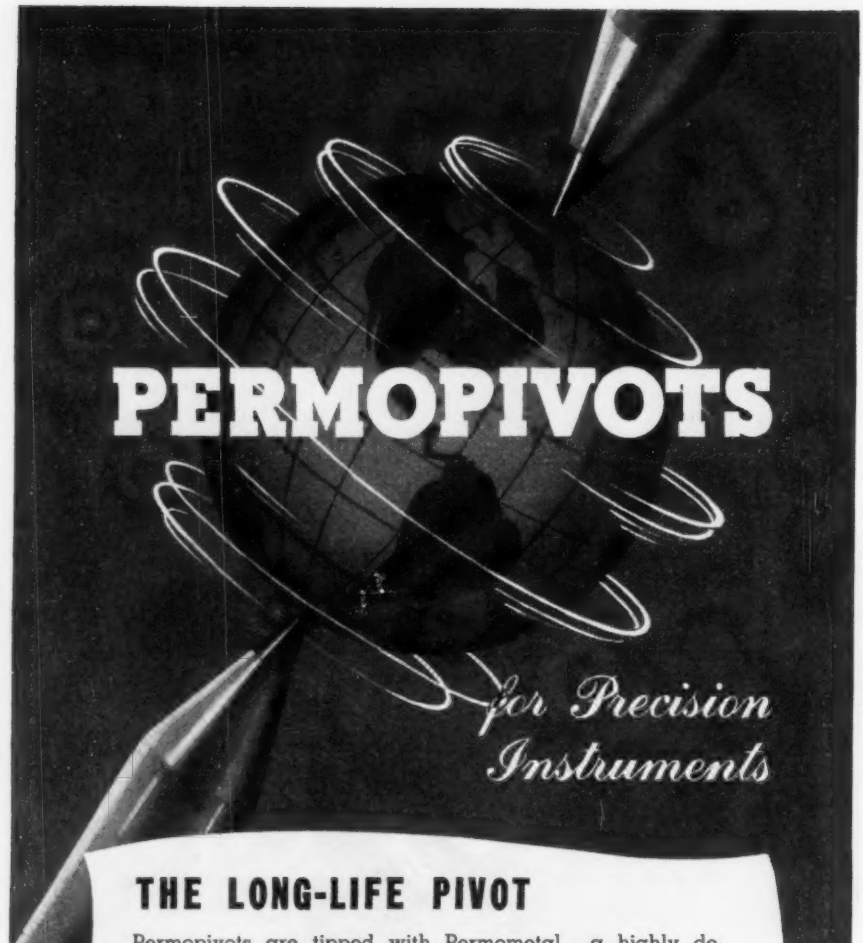


## THE LONG-LIFE PIVOT

Permopivots are tipped with Permometal, a highly developed precious metal alloy . . . the product of Permo's own metallurgical laboratory. The unique qualities of Permometal make it ideal for tipping precision pivots. It has an extremely low coefficient of friction, eliminating the need of oil . . . it is non-corrosive and non-abrasive. Actual tests definitely prove Permopivots keep precision instruments accurate longer.

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industries, etc. Its primary element is a direct-action type pressure gage designed to withstand shock loads on "surging" lines which are "tough on gages." This gage operates a snap-action switch. Easily readable scales are provided for adjustment of cutout and differential. Pressure connection ¼" Am. std. pipe tap. Electrical connection provided for ¾" conduit. Switch is mounted on a steel base with two 9/16" mounting holes and is covered by a 14 gage sheet metal housing with removable front. Plexiglas window permits observation. Electrical characteristics (a.c.) 10 amps. 125 volts; 5 amps. 250 volts; 2 amps. 600 volts; ½ hp. 115/230/460 volts. All switches are single-pole, with normally-closed, normally-open or double-throw contact arrangements. Also available as a maintained contact type switch with manual reset. Various pressure ranges available.—*Hercules Elec. & Mfg. Co., 2416 Atlantic Ave., Brooklyn 33, N. Y.*

## Glass Surface Plate

New "Opti-Flat" is an optically polished glass master surface plate, flat to 50 millionths of an inch, giving the toolmaker an extremely accurate surface from which to

begin. "Opti-Flats" are said to be extremely resistant to abrasion. They are 2" thick for the 12" size and 3" thick for the 16" size to prevent warpage and breakage. They are inspected by means of optical flats, are annealed and free from strain, and "will not distort over a period of time."—*The George Scherr Co., 200 Lafayette St., New York 12, N. Y.*

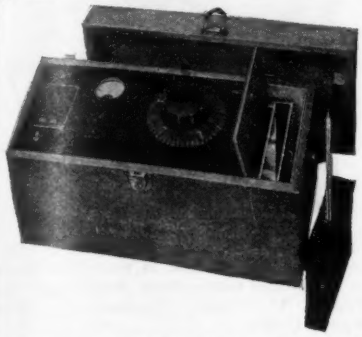
## Monochromatic Light Source

New "DoALL Monolight" uses helium to provide monochromatic light, is said to have large adjustable capacity as well as compactness. Helium is obtained in a highly purified form. The yellow light is high in intensity, giving greater illumination for distinguishing the "fringe" or interference

hand. Light from this lamp, when observed through "DoALL Optical Flats," produce interference bands of 11.6 microinches. It is possible to read variations in flatness within millionths of an inch. Capacity—Maximum height lamp to table, 12"; minimum height lamp to table, 8½"; projection head tilts 90° up and 21° down; rotates 360°; projection head removable for inspection in hand. Net weight 12 lbs. Operating current, 110-volt 60-cycle single-phase.—*Continental Machines, Inc., 1301 Washington Ave. So., Minneapolis 4, Minn.*

## Moisture Meter for Granular Materials

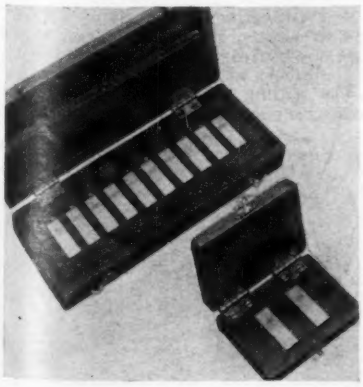
New "TAG Dielectric Type Moisture Meter" completes maker's line of rapid electrical moisture testers. It is designed for measuring moisture content of powders



or granular materials such as dehydrated foods, soaps, flour, plastic molding materials, etc., for which maker's other electrical conductance instruments are not suitable. It is designed for the precise measurement of the dielectric property of a test sample. It is said to be electrically simple but extremely sensitive. Sensitivity is said to be the result of a unique electronic method. Advantage is taken of the fact that the dielectric constant of water is about 80 while that of common substances is less than 10. Thus, a slight change in moisture content has a marked effect (in nearly all cases) on the dielectric constant of a substance. With this instrument, moisture determinations can be made in less than two minutes. Models are available for operation on 110 or 220 volts a.c., various frequencies. None is made for d-c. operation.—*C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn 5, N. Y.*

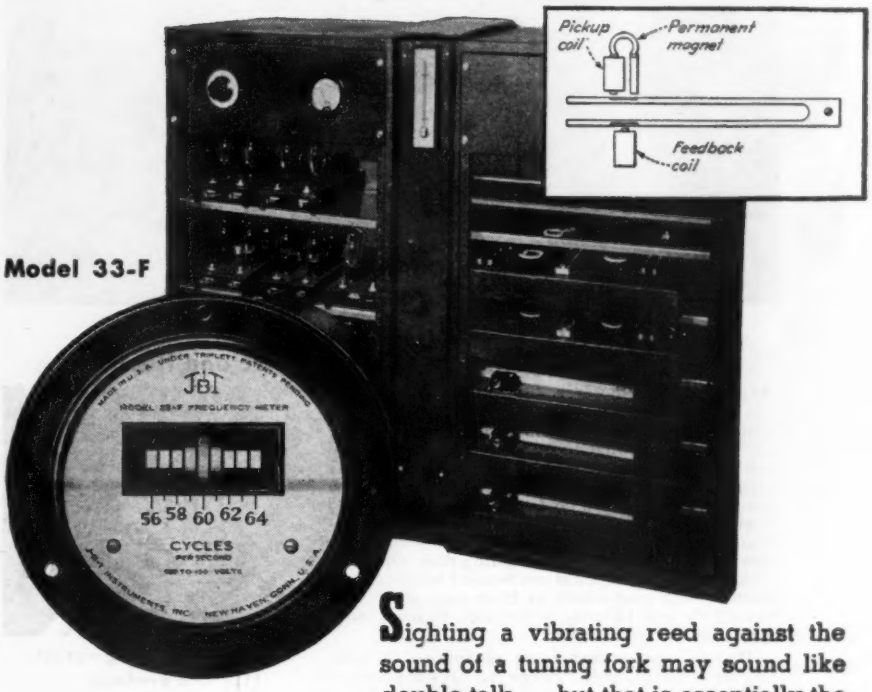
## Tungsten Carbide Gage Blocks

New gage blocks are made of tough, wear-resistant tungsten carbide, are said to be held to extremely close limits, often well within claimed tolerances. All-carbide gages are available in three sets: of ten, two, and two blocks respectively. There is also announced one set of 81 steel blocks with two 0.050" tungsten carbide wear blocks. The ten-block carbide set ranges in size from 0.050" to 0.0509" in steps of 0.0001". The two smaller sets are intended primarily to be used as wear blocks with steel gage blocks. One contains two 0.050"




WIRED FOR SIGHT

**Advanced Technique For Calibration of Reed Frequency Meters**




Sighting a vibrating reed against the sound of a tuning fork may sound like double talk . . . but that is essentially the principle in the exacting process of J-B-T Frequency Meter calibration.

Tuning forks are the most dependable source of mono-chromatic vibration frequencies, so J-B-T engineers devised equipment, the *only* equipment of its kind, to translate the frequencies of temperature-controlled tuning forks into electronic impulses. These impulses are delivered to the stroboscopic and electronic calibration equipment at the assembly and inspection stations where they are used *visually* to prove the accuracy of every J-B-T Frequency Meter reed. And still not satisfied, J-B-T engineers check these master tuning forks daily against time signals from the Bureau of Standards.

The superiority of this equipment for frequency testing, exclusive with J-B-T, is recognized by authorities in the electrical industry and in the war effort. It is one of the reasons why J-B-T Meters can be guaranteed permanently accurate to ± 0.3% or better.

Send for illustrated bulletin VF-43, with supplements on 400 cycle meters, and the new compact 2½ inch meters.

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For all 3½" instruments, black molded cases are now available to meet highest government standards and the mounting dimensions of ASA C 39.2—1944 and proposed JAN-I-6.

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## Ingenious New
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**Presented in the hope that they will prove interesting and useful to you.**

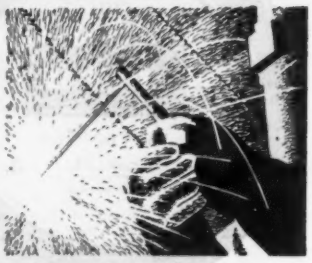
### Revolutionary Hy-cycle Automatic Arc Provides Complete Control of Arc and Heat

**At last, a development that automatically starts the arc before the welding electrode actually comes in contact with the work! Eliminating the "pecking" or "scratching" that so often creates tension and operator fatigue. Its many advantages contribute largely to saving time and labor because an operator can be trained in far less time than usual, and higher speeds can be obtained. This hy-cycle automatic arc unit, called "Missing Link," permits the operator to weld with any welding rod, bare steel or alloy. Rods that could not be used before can be burned with ease—such as bare mild steel, dust coated, reverse polarity, aluminum, bronze, stainless steel, etc., AC or DC.**

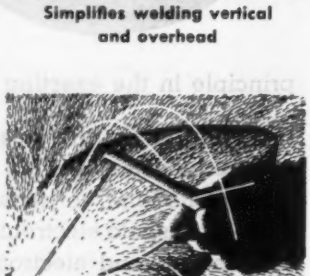
**One** of its most important advantages is welding light gauge. Light gauge requires low heat—making many jobs almost impossible for ordinary methods. Since the "Missing Link" starts automatically on as low as one ampere of heat, the welding of light gauge sheet can be done with surprising speed with no time out for "pecking" and "sticking."

**You** all know that our fighting men need the finest quality materials that we here at home can produce. That goes for Wrigley's Spearmint Gum, too. Although our stock pile of quality raw materials is getting lower and lower we are maintaining our standards of quality. Naturally, we are forced to limit production. So we are giving priority where it is needed most—and where you want us to—our fighting men and women overseas only. Because chewing gum is essential to them—they are getting all of our limited production of Wrigley's Spearmint Gum.

*You can get complete information from Mid-States Equipment Company, 2429 S. Michigan Ave., Chicago 16, Ill.*



**Simplifies welding vertical and overhead**



**Makes it easy to weld light gauge work**

Y-133

# To the Instrument Man With IDEAS

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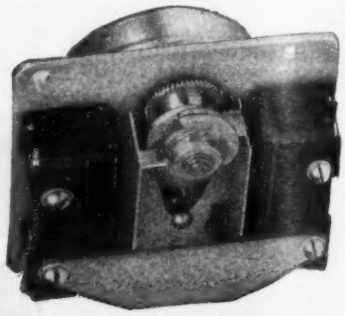
blocks; the other contains two 0.100" blocks. Shown here are the ten-block set and the two-block set, size 0.050". Among other advantages claimed for Jansson Carbide Gage Blocks is remarkable ease with which they wring to form combinations, a factor of particular importance in handling small sizes. All sets are packed in durable, attractive cases.—*Jansson Gage Co., 19208 Glendale Ave., Detroit 23, Mich.*

## Two-circuit Time Delay Relay

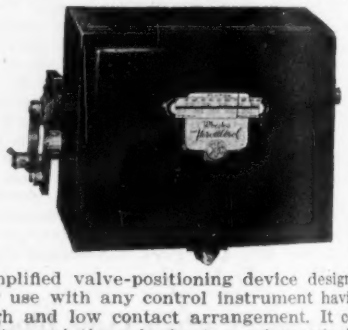
New "Type TDSA" and "TDSB" Time Delay Relay is designed to provide a definitely varied operation of one circuit in relation to the second circuit. It is arranged



for surface mounting for either front or rear connections and is especially designed to withstand momentary shock conditions.—*The R. W. Cramer Company, Inc., Centerbrook, Conn.*

## Valve Positioner

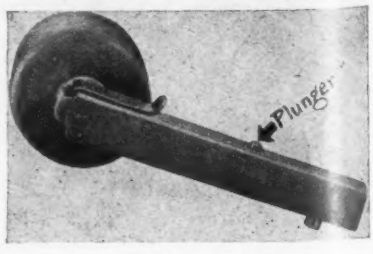
New "Throttltrol" is designed to correct variations in heat requirements of furnaces and process equipment by positioning a valve in the fuel line. It is essentially a



simplified valve-positioning device designed for use with any control instrument having high and low contact arrangement. It corrects variations in heat requirements due to changes in load, control settings, air and fuel pressure, Btu values and combustion efficiency. At a given setting, it will permit a fuel valve to open only the desired distance when the two-position control instrument is in its ON position. In this manner, it permits a more even and constant flow of fuel to burner and minimizes danger of overshooting when fuel supply is either full on or entirely off.—*Wheelco Instruments Co., Harrison & Peoria Sts., Chicago 7, Ill.*

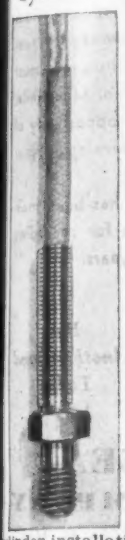
## Torque Wrench

New "Livermont Torq-Stop Wrench" is said to solve problem of applying threaded plastic closures to glass and other types of containers at correct tightness to insure proper sealing without damage to closure, gasket or container. When proper torque



ad is reached, new wrench gives both an audible and a tactile signal. Audible signal is a sharp click; tactile signal is transmitted by a small blunt plunger which taps operator's palm. A Micarta head, built to fit caps to be tightened, operates without marring the material. These wrenches are set at predetermined torques of 8 to 750 inch-pounds in accordance with requirements of user. They are sealed at setting and will not vary more than ±2% so that inexperienced users can immediately achieve efficient, rapid operation.—*Richmont, Inc., 45 W. 7th Street, Los Angeles, California.*

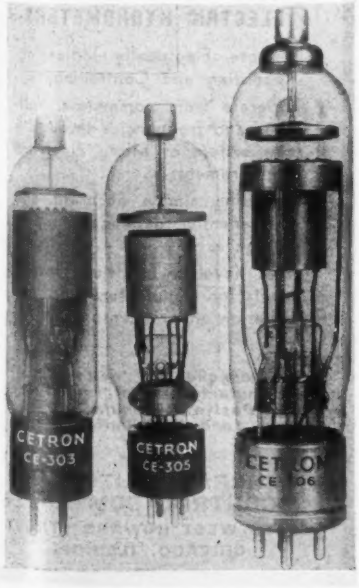
## Cylinder Base Thermocouples



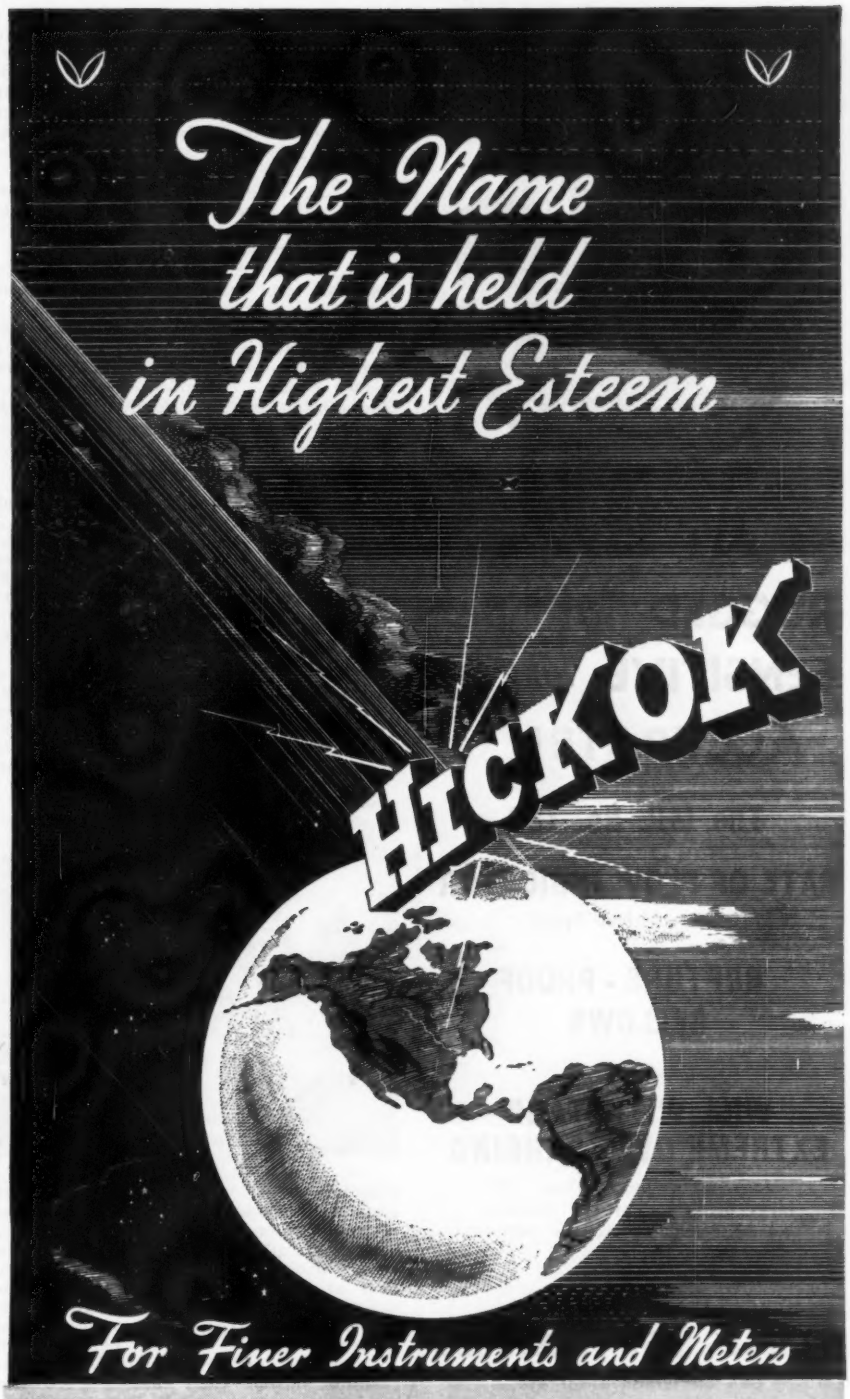
New imbedded type base thermocouple is said to supersede the orthodox staked type base unit. Main features are said to be simplicity of design, ease of installation and/or removal. Use of selected and checked thermocouple wire of controlled accuracy is said to insure primary purpose, i.e., to indicate high cylinder wall and piston temperatures. It is known that piston temperatures have the same effect on detonation and allowable fuel consumption as high cylinder head temperatures. High piston and cylinder wall temperatures also cause troubles. These thermocouples are made as individual units or woven in harnesses with any specified number of units for compact and simplified multi-cylinder installation.—*The Revere Company, Dept. I, P. O. Box 304, Wallingford, Conn.*

## Industrial Thyratrons

Three new electron tubes for industrial control purposes are announced: (1) New "CE-303" is a 1-amp. xenon-filled Thyratron especially designed for the industrial field and suitable for use in a wide variety of equipments such as industrial control (including welding control), motor control, and controlled rectifiers. Being gas-filled, this tube is quick-heating and is free from effects of large temperature changes. Inverse peak voltage rating is 700 volts. Because of its special design, "CE-303" draws low critical grid current, maximum limit being 5 microamperes. It uses a standard 4-pin base. (2) New "CE-305" gas-filled Thyratron is a medium-current tube that will stand higher-than-usual voltage. Be-








At all the Fighting Fronts on land, aboard ship and in the air, the Army, Navy, Signal Corps and Air Corps are using thousands of HICKOK panel meters, aircraft meters, portable meters and other electrical instruments with confidence in their utmost reliability. What greater tribute could be paid to a good name that has been symbolic of fine instruments for more than a third of a century?

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**WILL WITHSTAND EXTREME OVER RANGING**

Unique rupture-proof Bellows Unit takes the place of the mercury column commonly used in instruments of this type.

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**HANDLES HIGH PRESSURES**

Can be furnished for use with line pressures up to 1,000 lbs. psi.

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**REQUIRES LITTLE SPACE**

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fore the introduction of this type, it is said, no gas-filled tube in this current and voltage range had been available. "CE-305" is particularly suited to resistance welder control, motor control, and controlled rectifiers. Being gas-filled, it is especially suitable where large temperature changes are involved. It is quick-heating. It has a maximum peak inverse rating of 1,700 volts. It has a d-c. output current rating of 2 amperes. (3) New "CE-306" is a gas-filled grid control tube or Thyratron designed to give high efficiency with a long life. It is rated at 6 amperes continuous load. Peak forward volts (max.) 750. Peak inverse volts (max.) 1250. Mechanical dimensions: height 9½", diameter 2". It is designed for general industrial electronic use, such as motor control for various uses, resistance welder control, controlled rectifiers, etc.—*The Continental Electric Co., Geneva, Ill.*

## Precision Gage Instruments

New complete line of gage instruments, for broader application of gage blocks, is constructed to the same accuracy as precision gage blocks and is not to be confused with ordinary measuring attachments. Set comprises twenty instruments which, in combination with gage blocks, will perform "practically all" precision measuring functions. With gage holders and caliper bars, any type of "go," "no go" snap gage can be made up in a matter of seconds, accurate to millionths of an inch, and as easy to use as any standard snap gage. Instruments also provide means to make a precision height gage, accurate to microinches and

fulfilling all the duties of a standard height gage. Set includes trammel points and center points for checking layouts, scribing arcs or parallel lines, checking center distances or thread lead. For determining flatness of finished work there are included quartz optical flats and a high-intensity monochromatic light. For precise angle measurement a 5" sine bar enables angles to be checked to four seconds of arc. An adjustable vernier gage enables gage block combinations to be made in increments of ten microinches. All these new gage instruments receive the same stabilization by treatment at −120°F. as do maker's gage blocks. Sold separately, each instrument is supplied in a wood case. Entire set of instruments is available as "a complete inspection laboratory," enclosed in a specially made walnut case.—*Continental Machines, Inc., 1301 Washington Ave. South, Minneapolis 4, Minnesota.*

## Four New Industrial Types of Electron Tubes

Said to be typical of the wide variety of special electron tube types being developed and made available by undersigned manufacturer are four new types whose functions range from production of high-frequency power for industrial heating applications to the measurement of low light intensities of the order of starlight. Quartet includes a 25" high forced-air-cooled transmitting triode weighing 235 lbs. and a 1⅞"


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Our production of special clock movements and clockwork mechanisms for recording instruments must wait until this war is won. Meanwhile, we would welcome the opportunity of working with you in developing your post-war designs.

Remember, Chelsea has been making special movements for recording instruments for many years.

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Remote Electrically Indicating, Recording and Controlling.

Operate from commercial voltages and frequencies through a new system of Micro Electrical Measurement.

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•

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LUXTRON*
PHOTOCELLS

Give Simple Means of Precision Control

This pigtail-contact model is only one of a series of mountings and indicates only one of the complete range of Luxtron* cell shapes and sizes available.

Circuit simplicity contributes to a constant flow of power. The ability of Luxtron Photocells to operate instruments and instrument relays, without amplification, removes the hazards of complex circuits.

This fact alone recommends their application to precision control problems. Another quality is their exceptional resistance to vibration, shock and general mechanical violence. These factors assure long service and unusual adherence to calibrated accuracy.

Engineering inquiries are always welcome.
Illustrated data sent on request.
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82 Meadow Street New Haven 10, Conn.


Thyratron weighing half an ounce. (1) Forced-air-cooled "RCA-9C22" and (2) its "sister" tube, water-cooled "RCA-9C21," are both suited for use in large units for high-frequency heating. A pair of 9C22's, operated as unmodulated class C oscillators, will provide a tube output up to 130 kw. A pair of 9C21's under same conditions will furnish up to 200 kw. These new types may be used with maximum ratings at frequencies as high as 5 Mc. and with reduced ratings at frequencies up to 25 Mc. Design features include a multi-strand single-phase tungsten filament, and an entrant metal header which provides short internal connections between filament and filament terminals, providing an extremely short, low-inductance path to the grid. This feature is of particular importance for operation at the higher frequencies. (3) New "RCA-2D21" xenon-filled Thyratron, despite its tiny size, provides stable operations and a high control ratio for a variety of functions as an electronic switch. It will carry 0.1 amp. plate current continuously, and for periods up to 6 seconds out of 30 will safely carry 0.5 amp. Xenon filling obviates limitations imposed by use of mercury on mounting position and need to restrict motion while in operation. Other features of this gas-type tetrode include quick heating (anode voltage may be applied 10 seconds after application of heater voltage), wide temperature range (—55 to 90°C. with little change in operating characteristics), low internal drop (only 8 volts), low preconduction current, versatility of control (either by shield grid or by control grid), and high sensitivity. (4) Perhaps most sensational is new 9-stage multiplier phototube "RCA-931-A" which is capable of amplifying signals up to 200,000 times and more. This sensitivity is made possible by secondary emission: cathode electrons are impelled against nine successive dynodes before they reach the plate, electron current being multiplied by release of secondary electrons at each dynode. Operated at 100 volts per stage, "931-A" has a sensitivity of 2 amperes per lumen (more than three times that of "RCA-931" which it supersedes). Because it does not need the high-gain amplifier stages required with conventional phototubes, external sources of electrical noise, such as arcs produced by grid leaks, are eliminated, and a favorable signal-to-noise ratio can be attained for extremely low light levels. A typical application of "931-A" is in quantitative spectrographic analysis, the tube and its associated circuits being substituted for the photographic plate commonly used in such analyses. This phototube method of spectrographic analysis is used in vitamin measurements.—*Radio Corporation of America, Camden, N. J.*

## Thermometer Bulb Insert

New "Rosán Thermometer Bulb Insert" is announced by makers of the "Rosán Locking System" for threaded inserts and studs in all materials. It is said to be adaptable to both old and new type thermometer bulbs. Reason for its introduction is that difficulty is encountered by airplane manufacturers (and others) when installing thermometer bulbs in soft metals, by reason of stripped threads. When this happens, tube section must be replaced or, in a casting, flange must be removed and another welded in its place. "Rosán Thermometer Bulb Insert" is made of steel and inserted in soft metals. This prevents usual crossing of threads in soft material of bulb receptacle. If insert is damaged, it can be easily replaced in such installations without removing plumbing or tank, and without using oversize replacements which involve redrilling and retapping operations. Insert operates on the same principle as other applications of Rosán locking system. Serrated collar at head of insert engages its teeth with inner teeth of locking ring which is serrated both inside and out. Outer teeth or splines of locking ring broach their way into the parent material at the wall of a


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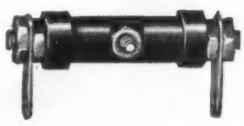

"Coprox" Model CX-1C2B1, a center tap, full wave rectifier. Completely enclosed in Bakelite. Low capacitance. Rectifies high frequency current. Conservatively rated up to 4.5 volts A.C., 3.0 volts D.C., 500 microamperes D.C. Other models and capacities to meet all needs.

Special terminals, or pre-soldered lead wires, prevent overheating during assembly. Standard units sealed with waterproof lacquers, critical-application units potted in wax. Standard "pellets" gold coated on front surface, forming positive contact; for critical applications, gold used on both sides. High leakage, but very low forward resistance. Highly adaptable mountings.
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ELECTRO-PNEUMATIC RELAY

TIME DELAY

COMPACT:
4 IN HIGH
2½ IN DEEP
2½ IN WIDE

WEIGHT:
1½ POUNDS

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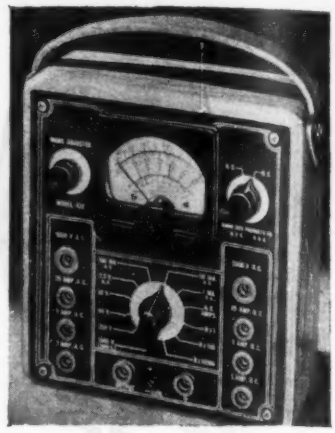
AMERICAN GAS ACCUMULATOR COMPANY


counterbore when struck with a hamm or a drive tool. This makes the insert stud an integral part of the parent mat rial. When necessary, by a simple bori operation, insert may be removed for placement without damage to the surroun ing material. Broaching splines of locki ring are so finished, it is said, that th leave no sharp edges or distortion of mat rial which might be possible points of fa ure in service.—*Bardwell & McAlister, In 911 North Orange Drive, Hollywood Calif.*

## Portable Circuit Testers

Two new portable multiple-range teste are announced: (1) "RCP Model 422 Supe tester" is said to be equivalent to 27 ind vidual instruments in one compact un "with very low and very high ranges Features: Current measurements in bo a.c. and d.c. up to 25 amps; Voltage mea urements in both a.c. and d.c. up to 5,0 volts; High voltage not applied to selecto switch nor to general test circuits. 3" squa indicator with movement of 200 microam



or 5,000 ohms-per-volt sensitivity on d- voltage measurement. Resistance measure ments up to 10 megohms. Batteries replace able without a soldering iron. Supplied com plete with batteries in 6½" × 7" × 2¾ wood case with strap.

(2) New "RCP Pocket Multitester Model 420" is said to provide accuracy of measurement comparable to that found in larger RCP models although it is only 6⅜" × 3½" × 3" and weighs only 25 oz. Indicator movement guaranteed accurate within 2%. Voltage multipliers are metallized matched pair resistors having a tolerance of 1%. Basic instrument is 0.400 mi croamperes. Decibel meter, output meter milliammeter and ohmmeter provide a tota of 23 ranges. A-c. and d-c. voltmeter up t 5,000 volts at 1,000 ohms-per-volt sensitivity This Multitester is supplied in hand-rubbed hardwood case complete with batteries ready to operate.—*Radio City Products Co. 127 West 26th St., New York 1, N. Y.*

## Enclosure for Aircraft Control Devices

New standard dust-tight enclosure fo housing combinations of aircraft control de vices accommodates various G-E aircraft control relays and contactors with ratings up to and including the G-E 100-amp. air craft contactor. It is completely gasketed made of aluminum, with cast aluminum end frames. Self-locking latch permits removal of cover of enclosure in a vertical direction without disconnecting wires or use of tools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*WRITE* for completely descriptive folder about the new Cadillac Glass Surface Plate. Available in sizes from 8x8" to 18x24" and in accuracies from .0002 to .0005. Prices range from $11 to $90. Is packed in an individual box, the top of which forms a protecting cover.

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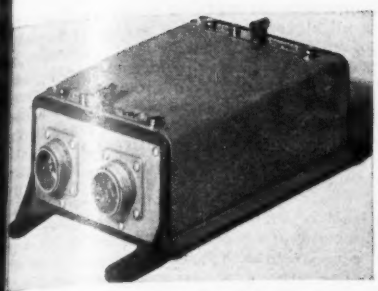
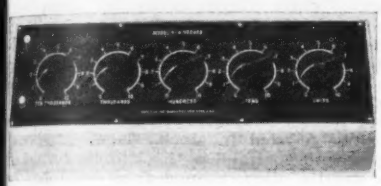


hus facilitating complete inspection. This atch also has a provision for wire-locking he enclosure. In addition, end plates are daptable for various sizes "AN" connectors r terminal posts. Enclosure is available in arious lengths up to 19" over all.—*Indus-rial Control Div., General Electric Co., chenectady, N. Y.*

## Decade Box

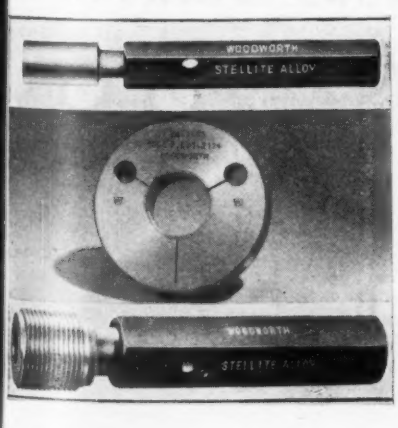
New "Model 5A" decade box provides a hoice of resistances from 1 ohm to 111,110 hms in steps of one ohm. Each decade is djusted to an accuracy of 0.1%. All re-



istors are non-inductively wound. Tempera-ure coefficient of wire is +0.0002 between 0°C. and 100°C. Wattage rating is 1 watt er decade (for short periods, permissible issipation is 2 watts). Terminal binding osts are heavy-duty type accommodating No. 10 wire. Panel is Bakelite, engraved y what is said to be a new cut-in process. Cabinet is hand-rubbed oak. Dimensions 8½" × 6½" × 3½".—*Superior Instruments Co., 227 Fulton St., New York 7, N. Y.*

## Stellite Alloy Gages

New plug and thread gages are made rom the hardest, most wear-resistant grade f Stellite alloy: from dense castings of a ew cobalt-chromium-tungsten alloy. Ac-ording to maker's engineers, these gages re setting new on-the-job records for wear esistance and accuracy (5 to 15 times life f steel gages) and are showing additional dvantages resulting from other character-stics of this hard stainless metal: (1) Co-efficient of friction of Stellite on steel, as easured by the angle of repose method, is .11 to 0.13; chrome plate on steel is 0.15 o 0.18; steel on steel is 0.30 to 0.40. These alues are relative but they indicate that Stellite has the advantage of more free ction. (2) Stellite has an oily or velvety eel; it has a low affinity for other mate-ials, does not readily seize or bind. (3) Concerning resistance to shock and impact, Stellite generally has ample tensile and



**This man at the bench is not a Hero with medals,** and no glory awaits him when his job is done. Unseen and unsung, he is on the job every day, working with hot glass, behind a fierce flame, with delicate fingers and skill, building one of the finest thermometers for his country's needs.

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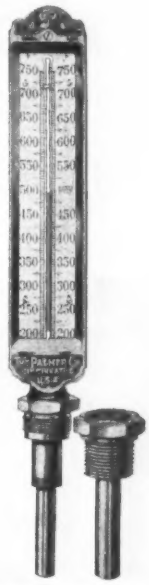

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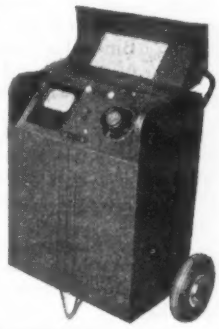
Let the HYPOT foretell the condition of your electrical equipment. In quick time you locate and repair insulation faults that would break down in operation. The HYPOT has ample capacity for all testing . . . has the exclusive "Burn and Test" feature . . . meets all AIEE specs . . . safe, sturdy, compact, easy to control. Write Dept. B today!



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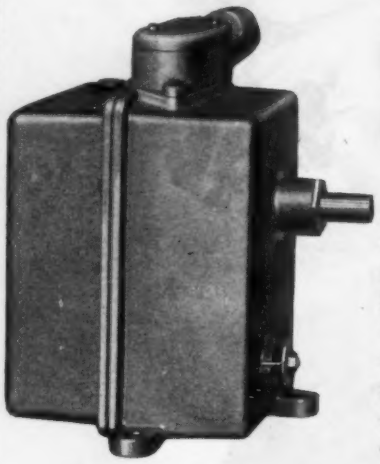

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This sizeable (11" x 10⅜" x 9½" overall) power unit, which operates off line voltage, is ideal for applications requiring a heavy-duty high-torque (350 to 750 lb. in.) motor and gear reduction with built-in limit switches. Common uses include: • Regulation of heavy dampers in combustion control systems. • Operation of large butterfly valves and blast gates. • Operation of large air and gas valves, multiple ratio fuel valves, and industrial fuel carburetors. ★ Write for Bulletin F-1912 "Power Units".

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## "QUICKSET" BIMETAL THERMOREGULATOR

Range: —73° to 538°C.
Sensitivity: ±0.05°C. for liquids; ±0.01°C. for air (or better).
Quickly adjusted to desired temperature.

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Adjustable throughout the entire temperature range.

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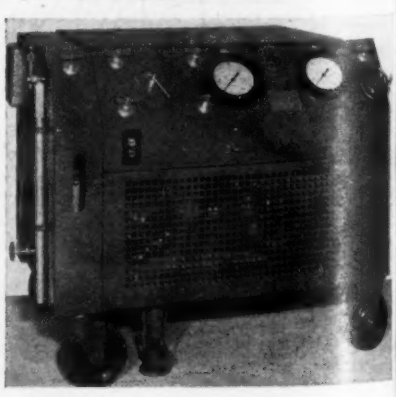
compressive strength to resist breakage under all stresses to which a gage is normally subjected. (4) Coefficient of expansion is close to that of steel and cast-iron, so that temperature fluctuations cause no inaccuracy when gaging parts of steel or cast-iron. (5) Low coefficient of thermal conductivity makes Stellite less sensitive to heat and temperature changes than steel when gaging large parts and when foreign heat influences are present in and about a gaging operation, such as heat from the hand, machine and atmosphere. (6) Stellite alloy is extremely stable (practically inert) and will not lose size or shape over long periods of time. (7) Stellite alloy is resistant to fumes and acids, including body acids. It does not rust and does not require special greasing or oiling to prevent it. Stellite gages can be stored in gage cribs without a rusting hazard. (8) Stellite alloy is virtually non-magnetic. Accordingly it will not pick up minute particles of steel which cause excessive wear on both the gage and the inspected part. Through close cooperation of undersigned manufacturer and Haynes Stellite Co. development of the casting form progressed into practical blank sizes up to and including 1½" diam. to American Gage Design Standard. Cylindrical and thread plugs up to and including ¾" O.D. are made solid both gage member and shank being cast solid Stellite. Gages above ¾" diam. and including 1½" are bushing type with a standard tapered steel shank brazed to Stellite bushings. Castings for gage blanks up to 1½" are pre-fabricated to blank form and then stored preparatory to finishing. In near future, completed standard thread plugs will be carried in stock. Gages of special design or special lengths will be furnished in Stellite alloy, ground from solid bar or with steel shanks brazed to the Stellite, as the case may warrant. Cylindrical and thread plugs over 1½" and including 4" of AGS trilock design will be made to order; blanks for these sizes at present are not carried in stock. These gages will be made of cast Stellite alloy bushings with aluminum insert. (This design has advantage of lighter weight than steel.) Plain ring gages are being considered; will probably be made of a cast Stellite alloy bushing with an outer casing of aluminum. Thread ring gages are also being made but development is still going on.—*N. A. Woodworth Co., Ferndale, Mich.*

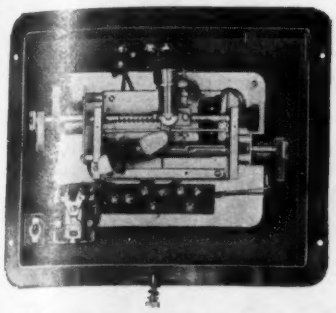
## Hydraulic Test Machines

New line of hydraulic test machines which inspect all types of production hydraulic devices and components, and which fill, filter and check hydraulic systems, comprises various types and sizes, including stationary and portable models, driven by gasoline or electric motors. New "Model HS101" is designed for inspection and operational testing of any single or complete line of hydraulic components, and for research and development testing. "Model HS100" was developed specifically for testing airplane hydraulic systems and their components. Models "HS102" and "HS105" (the latter illustrated) are both portable, and are designed for testing airplane hydraulic systems on the final assembly line or on the field.—*Greer Hydraulics, Inc., 38 West 60 St., New York 23, N. Y.*



## Process Power-input Controller

Two new "Inputrols" are designed to control input of power, heat or flow of liquids or gases to any process equipment. They are offered in automatic and manually



set models. Basic elements of the instruments are a mercury switch mounted on a carriage, a rotating horizontal cylindrical cam driven by a small synchronous motor, and a spiral on which the mercury switch carriage is mounted. In automatic model, which is used with a pyrometer, spiral is turned automatically to position mercury switch carriage at proper point along rotating cam. In manual model, spiral is set by hand to input point desired by equipment operator. "Inputrol" scale is illuminated and in terms of percent of maximum input. If its pointer is at 60, for example, instrument's mercury switch will be in its ON position 60 percent of the time, or 36 seconds of each minute. "Inputrols" may be flush or surface mounted.—*Wheelco Instruments Co., Harrison and Peoria Sts., Chicago 7, Illinois.*

## Moisture-proof Time Delay Relay

New "Type TD-4" is said to be an extremely simple and compact time delay relay for surface mounting, that automatically resets on power failures. It has a spe-

cial overtravel mechanism which delays complete recycling in case of momentary power interruptions. Further, it has a moisture-proof surface type mounting case. It is used for controlling the closing of plate circuits as in radio transmitters or rectifiers. —*The R. W. Cramer Company, Inc., Centerbrook, Conn.*

## Adjustable-magnification Comparators

New line of "DoALL" comparators is said to be complete. Basic feature of each comparator is wide range of magnification, said to enable one comparator to do the work which formerly required as many as four: each has four magnification ranges. Thus, a workpiece may be checked to determine size variations of one millionth inch and, on the same comparator, a workpiece can be checked to determine size variations of four thousandths of an inch. Among other features: For measuring thick or thin sections, as well as for hard and soft materials, spindle pressure is readily adjusted by a calibrated dial located at top of comparator. Spindle movement is magnified electrically. There are no moving parts which could cause spindle to stick or bind. Spindle head is provided with an adjusting collar for raising spindle to accommodate

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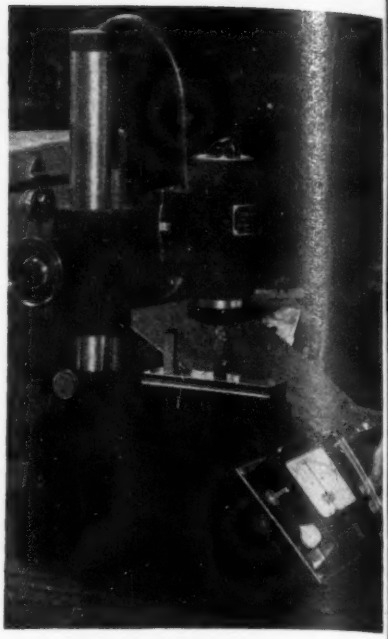


the work and is also provided with a hair-line adjustment knob for setting indicating pointer on comparator dial. Gage head swivels 360° in horizontal and vertical planes, making it a simple matter to check irregularly-shaped parts or multiple-jig fixtures. Protractor shows angle to which gage head is tilted. Gage head can be removed from stand and used on a surface plate, machine tool, multiple-gaging fixture, or for any other special application. Broad heavy base provides housing for calibrated dial. Both work anvil and calibrated dial are at equal distance from operator's eyes, facilitating operation and greatly reducing possible human error. Differential electric circuit minimizes expansion due to temperature changes and drifts due to line voltage fluctuations. Three models of new comparators are offered, each having four ranges of magnification: "Model 10," having a magnification range of 100,000; 50,000; 10,000 and 5,000, will measure variations from one to four hundred microinches. "Model 20" has magnifications of 10,000; 5,000; 1,000 and 500. "Model 30" has magnifications of 2,000; 1,000; 200 and 100. All "DoALL" Comparators operate on 110-volt 60-cycle, a.c. and are protected so that accidental plugging into d-c. outlet will not damage comparator. — *Continental Machines, Inc., 1301 Washington Ave. South, Minneapolis 4, Minn.*

---

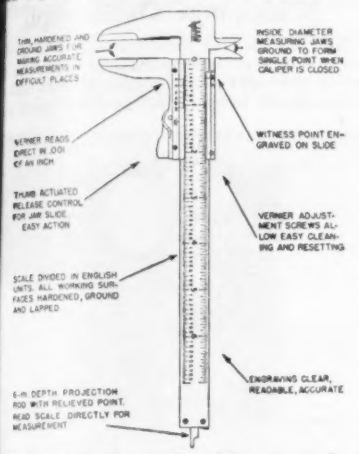
### Electrical Tachometer

New electrical Tachometer is claimed to be "for every speed measuring requirement." Generator is of simplified design, smaller, equipped with special sealed ball bearings and a permanent-magnet rotor, designed for long trouble-free operation. No brushes, commutators or gears are used. Indicator scale may be graduated in r.p.m., m.p.h., f.p.m., g.p.m., etc. Guaranteed accuracy is 0.5% of full-scale. Each tachometer is tested and calibrated before shipment. Direct scale

dings up to 50,000 r.p.m. are possible. del illustrated is designed as a portable ting instrument. Generator has plastic using to permit easy hand hold. Four rub- tips are provided so that speeds of "any e shaft" can be determined. Complete fit—generator, indicator, electric cord, essories—is supplied in a handy carrying e. Manufacturer guarantees tachometer 10 years.—*R. B. Brigham Co., 327 16th , Toledo, Ohio.*

## Vernier Caliper

New vernier caliper is designed to meet esent wartime manufacturing conditions. reads outside diameter, inside diameter, d depth. Depth gage is an integral part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f the new instrument, which is made in ne size only: 6″ between jaws. It has a ull 7″ of graduations, thus making possible full 6″ reading. Caliper is constructed of tel precision ground, jaws hardened and apped. One edge is divided in thirty-sec- nds, the other in fortieths which read in housandths in the vernier. In addition to he vernier there is a witness point for eading the thirty-second scale. Vernier is djustable to compensate for wear.—*Vard nc., 2961 E. Colorado Blvd., Pasadena 8, alif.*

## Lens Cleaning Fluid for Surface-coated Glass

New "Opti-kleen" lens cleaning fluid is aid to be the answer to the problem of fficiently cleaning surface-coated glass. (A eflection-reducing process, surface-coating as introduced as a wartime necessity, and ill be a peacetime "must.") New fluid was pecially designed to keep pace with this ns improvement. Reflection-reducing coat- gs may be severely damaged by the use of cleaning material containing wax, so this oubly-effective solution is characterized by bsence of all solids, which eliminates possi- ility of residue from cleaning fluid being eft on surface of glass.—*Bell & Howell o., 1801 Larchmont Ave., Chicago, Illinois.*

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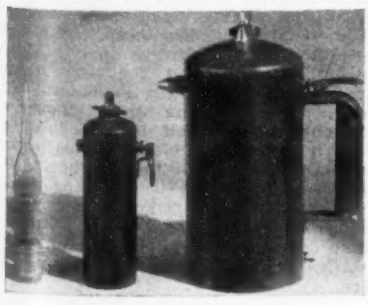

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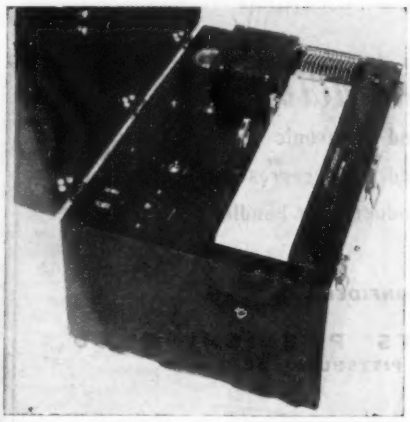

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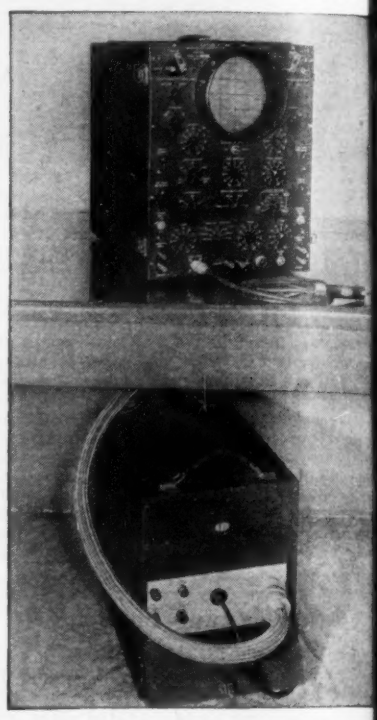

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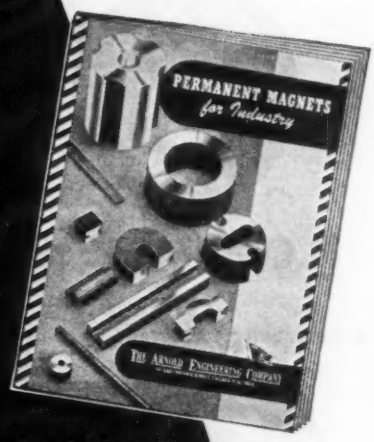


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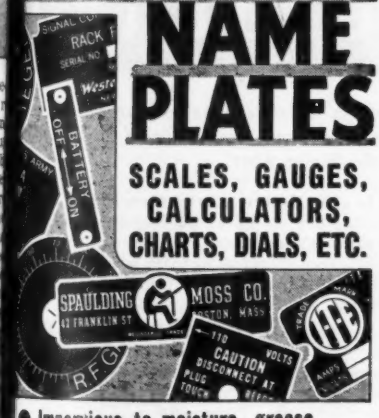


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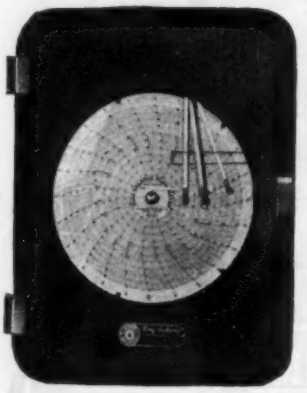

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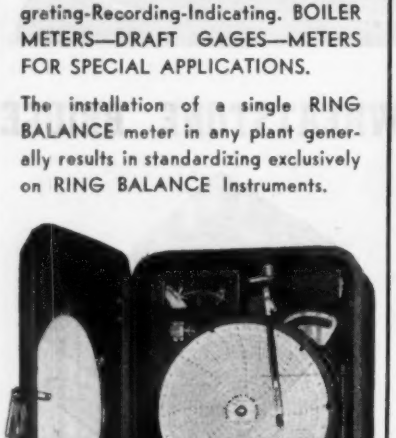

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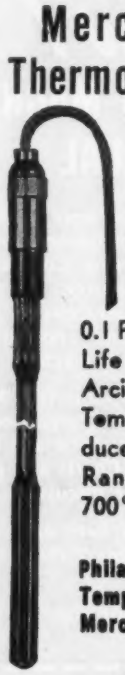

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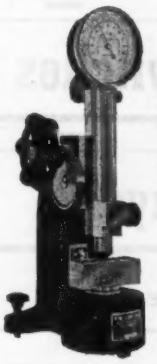

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# Manufacturers' New Literature

In this department we report new literature pertaining to Instrumentation, received from manufacturers. To assist in the War Effort we urge readers to request ONLY those bulletins which will be of value to them. Use the coupon on the facing page.

L-136 **Variable Resistors.** Bulletin, 8½" × 11", 8 pages. Specifications for standard and miniature type variable resistors. Outline drawings are used to illustrate the unit dimensions, and several pages describe numerous switch combinations which can be supplied with most units. Centralab, 900 E. Keefe Ave., Milwaukee, Wisc.

L-137 **Boilertrol.** Bulletin 515, 8½" × 11", 4 pages. A reducing regulator and gas fuel regulator for oil field boilers. This unit not only controls the fuel supply in accord with demands made on the boiler, but also acts as a reducing regulator to maintain a constant fuel pressure, compensating for the most extreme changes in gas supply pressure. It is stated that this unit will maintain steam pressure within 3 lbs. even under extreme changes in load. Natural Gas Equipment Inc., Petroleum Securities Bldg., Los Angeles, Calif.

L-138 **R-F Resonance & Coil Winding Calculator.** Leaflet, 8½" × 11", 2 pages. Instructions for using the Rapid Calculator Stock No. 37-955. Allied Radio Corp., 833 W. Jackson Blvd., Chicago 7, Ill.

L-139 **Boiler Ratio Meter.** Publication 4071, 8½" × 11", 12 pages, discusses "What Constitutes an Ideal Boiler Meter?" Installation details are also included. Cochrane Corp., 17th St. below Allegheny Ave., Philadelphia 32, Pa.

L-140 **Roll Thread Snap Gages.** Folder, 8½" × 11", 4 pages, illustrates details, construction and application of a gage for external threads. Vard, Inc., 2961 Colorado St., Pasadena 8, Calif.

L-141 **Electrical Resistance Instruments.** Bulletin 431, 8½" × 11", 4 pages, covers Attenuators and Potentiometers and gives characteristics and specifications. Tech Laboratories, 7 Lincoln St., Jersey City 7, N. J.

L-142 **Electronic Products.** Booklet, 12" × 8½", 24 pages, beautifully printed in color, illustrates plant views at Amperex Electronic Products, 79 Washington St., Brooklyn 1, N. Y.

L-143 **Moisture Meter.** Bulletin 126, 8½" × 11", 4 pages describes a new electric type moisture meter and includes operating instructions. C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn 5, N. Y.

L-144 **Pilot Light Assemblies.** Catalog, 8½" × 11", 24 pages, catalogues a great number of pilot light assemblies for panel board and instrument signaling. Gothard Mfg. Co., 1300 N. 9 St., Springfield, Ill.

L-145 **Automatic Soldering Iron.** Folder, 8½" × 11", 4 pages, describes a new soldering iron having a self-contained heat regulator which automatically maintains safe, efficient operating temperature at point. Sound Equipment Corp., 3901 San Fernando Rd., Glendale 4, Calif.

L-146 **Seedburo Equipment.** Catalogue 44, 6" × 9", 100 pages, describes and illustrates many instruments and devices for testing seeds and grains but which may find application in the testing of other granular materials. Seedburo Equipment Co., 223 West Jackson Blvd., Chicago 6, Ill.

L-147 **Relays and other Devices for Electrical Control.** Catalogue 4071-D, 8½" × 11", 104 pages, describes and illustrates relays: telephone-type; quick acting spring contact; slow-operating, slow releasing; slow acting; snap-action; quick-acting; mercury contact; weighted-spring time delay; vibrating-reed time delay; electric interlocking; as well as switches, keys, jacks, plugs, solenoids, etc. Automatic Electric Co., 1033 West Van Buren St., Chicago, Ill.

L-148 **General Radio Experimenter.** The June-July issue illustrates a number of instruments for "Meeting the Wartime Demand." General Radio Co., 30 State St., Cambridge 39, Mass.

L-149 **Measuring Flow Through Turbines.** Bulletin 420, 8½" × 11", 6 pages, describes operation principle of the MO meter which indicates, records and totalizes flow rate measurement of Differential Taps in Water Turbine. Taps are placed on turbine installations already operating, as well as within new constructions. Simplex Valve & Meter Co., 8th & Upland St., Philadelphia 42, Pa.

L-150 **Air-operated Precision Gage.** Folder, 8½" × 11", 4 pages, describes an air-operated precision gage for measuring diameters. Advantages are listed. Detrical Laboratories, Inc., Dept. 35, 417 Detroit St., Ann Arbor, Mich.

L-151 **Decade Resistance Box.** Leaflet, 8½" × 11", 1 page, illustrates a decade box which provides a choice of resistances from 1 ohm to 111,110 ohms in steps of 1 ohm. Superior Instruments Co., 227 Fulton St., New York 7, N. Y.

L-152 **Frequency Meters.** Bulletin VF-3-18, 8½" × 11", 1 page, illustrates a line of miniature vibrating-reed frequency meters. J-B-T Instruments, Inc., 441 Chapel St., New Haven 8, Conn.

L-153 **Tachometers.** Folder, 8½" × 11", 4 pages, illustrates several portable electric tachometers for speed measurements. Chicago Electric Tachometer Co., 800 N. Clark St., Chicago, Ill.

L-154 **Specialty Transformers for Aircraft.** Bulletin GEA-4238, 8" × 10½", 26 pages, covers transformers for the operation of gyro instruments, instruments and accessories, fluorescent lighting, aircraft indicator lights. General Electric Co., Schenectady, N. Y.

L-155 **Vibration Fatigue Testing Machine.** Folder, 8½" × 11", 4 pages, illustrates two testers: Model 10 HA produces vibration horizontally in simple harmonic motion; Model 10 VA produces vibration vertically. All American Tool & Mfg. Co., 1014 Fullerton Ave., Chicago 14, Ill.

L-156 **Surface Pyrometer.** Bulletin 3511-B, 8½" × 11", 6 pages, describes a contact pyrometer for surface temperatures which will give temperature readings of flat or curved, moving or stationary surfaces. Illinois Testing Laboratories, Inc., 420 N. La Salle St., Chicago 10, Ill.


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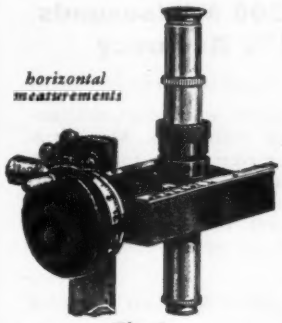


Fig. 1

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When used with the various types of support bases available they can be used as small comparators for horizontal linear measurements (Fig. 1).

The microscope mounted parallel to the slide permits depth measurements and micrometer focusing (Fig. 2).

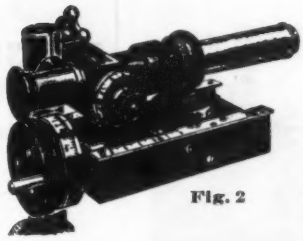


Fig. 2

Vertical orientation permits use as a small cathetometer for vertical linear measurements (Fig. 3). Interchangeability of microscope objectives and eyepieces permits a wide selection of magnifications.

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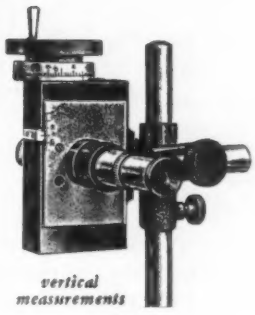


Fig. 3

*Send for Catalog M-138*

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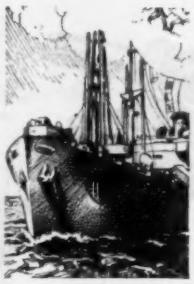
*Vital bearings for a Mark XIV Gyro Compass being inspected with a Spencer Stereoscopic Microscope.*

## A Ship—
## A Compass—
## A Microscope



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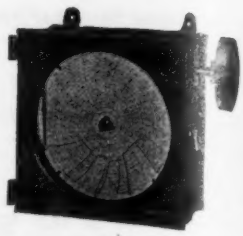

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